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U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF VEGETABLE PATHOLOGY.

BULLETIN NO. 6.

BORDEAUX MIXTURE
AS
A FUNGICIDE.

BY

D. G. FAIRCHILD.

PREPARED UNDER THE DIRECTION OF B. T. GALLOWAY, CHIEF OF DIVISION.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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PUBLICATIONS OF THE DIVISION OF VEGETABLE PATHOLOGY.

The Division of Vegetable Pathology, formerly a section of the Division of Botany, became a separate organization by act of Congress approved July 14, 1890. Since that date its bulletins have been numbered independently and in a separate series, but the following list includes the publications of the Division under its former as well as under its present organization. Nos. 1, 3, 4, and 6, omitted from the series of bulletins published by the Section of Vegetable Pathology, are publications of the Division of Botany, not relating to vegetable pathology. Only those documents marked with an asterisk are still on hand for distribution.

SECTION OF VEGETABLE PATHOLOGY, DIVISION OF BOTANY.

Journal of Mycology:

Vol. V. Nos 1, 2, 3, 4. Pp. 249, pls. 14. 1889–'90.
Vol. VI. No. 1. Pp. 44, pls. 2. 1890.

Bulletins:

No. 2. Report on the Fungus Diseases of the Grape Vine. Pp. 136, pls. 7. 1886.
No. 5. Report on the Experiments made in 1887 in the Treatment of the Downy Mildew and the Black Rot of the Grape Vine. Pp. 113, figs. 24. 1888.
No. 7.* Black Rot. Pp. 29, pl. 1. 1888.
No. 8.* A Record of Some of the Work of the Division. Pp. 67. 1889.
No. 9. Peach Yellows: A Preliminary Report. Pp. 254, pls. 37, maps and diagrams 9. 1888.
No. 10. Report on the Experiments made in 1888 in the Treatment of the Downy Mildew and Black Rot of the Grape Vine. Pp. 61, pls. 2. 1889.
No. 11. Report on the Experiments made in 1889 in the Treatment of the Fungous Diseases of Plants. Pp. 119, pls. 8. 1890.

Circulars:

No. 1. Treatment of the Downy Grape Mildew and the Black Rot. Pp. 3. 1886.
No. 2. Grapevine Mildew and Black Rot. Pp. 3. 1886.
No. 3. Treatment of the Downy Mildew and Black Rot of the Grape. Pp. 2. 1887.
No. 4.* Treatment of the Potato and Tomato for the Blight and Rot. Pp. 3. 1887.
No. 5. Fungicides or Remedies for Plant Diseases. Pp. 10, figs. 2. 1888.
No. 6.* Treatment of Black Rot of the Grape. Pp. 3. 1888.
No. 7.* Grape Vine Diseases. Pp. 4. 1889.
No. 8. Experiments in the Treatment of Pear Leaf Blight and the Apple Powdery Mildew. Pp. 11, figs. 2 1889.
No. 9.* Root Rot of Cotton. Pp. 4. 1889.

DIVISION OF VEGETABLE PATHOLOGY.

Journal of Mycology:

Vol. VI. Nos. 2.* 3.* 4. Pp. 45–207, pls. 3–18. 1890–'91.
Vol. VII. Nos. 1. 2. 3. Pp. 331, pls. 31. 1891–'93.

Bulletins:

No. 1.* Additional Evidence on the Communicability of Peach Yellows and Peach Rosette. Pp. 65, pls. 39. 1891.
No. 2.* The California Vine Disease. Pp. 222, pls. 27. 1892.
No. 3. Report on the Experiments made in 1891 in the Treatment of Plant Diseases. Pp. 76, pls. 8. 1892.
No. 4. Experiments with Fertilizers for the Prevention and Cure of Peach Yellows, 1889–'92. Pp. 197, pls. 33. 1893.
No. 5.* The Pollination of Pear Flowers. Pp. 110, pls. 12. 1894.
No. 6.* Bordeaux Mixture as a Fungicide.
No. 7.* The effect of Spraying with Fungicides on the growth of Nursery Stock. Pp. 41, figs. 17. 1894.

Farmers' Bulletins:

No. 4.* Fungous Diseases of the Grape and their Treatment. Pp. 12. 1891.
No. 5.* Treatment of Smuts of Oats and Wheat. Pp. 8, pl. 1. 1892.
No. 7.* Spraying Fruits for Insect Pests and Fungous Diseases. Pp. 20. 1892.
No. 15.* Some Destructive Potato Diseases. Pp. 8, figs. 3. 1894.
No. 17.* Peach Yellows and Peach Rosette. Pp. 20, figs. 7. 1894.

Circulars:

No. 10.* Treatment of Nursery Stock for Leaf Blight and Powdery Mildew. Pp. 8, figs. 3. 1891.
No. 11.* Inquiry on Grape Diseases and their Treatment. P. 1. 1891.
No. 12.* Inquiry on Rust of Cereals. P. 1. 1891.
No. 13.* Inquiry on Peach Leaf Curl. Pp. 3. 1893.
No. 14.* Inquiry on Rusts of Cereals. Pp. 3. 1894.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF VEGETABLE PATHOLOGY,
Washington, D. C., June 5, 1894.

SIR: I have the honor to transmit herewith Bulletin No. 6, of this Division, on Bordeaux mixture as a fungicide, prepared under my direction by my former assistant, Mr. D. G. Fairchild.

Six years ago the Section of Vegetable Pathology published a circular on fungicides. Since the publication of this circular the use of fungicides has become so extensive that it seemed desirable to bring together for publication in a bulletin all known facts on the subject, and to this task Mr. Fairchild gave a share of his attention for two years or more. It was the original intention to include in the bulletin all known chemical preparations tested for fungous diseases of plants, and with this end in view a somewhat extensive critical bibliography was prepared. The magnitude of preparing such a bulletin was not fully realized until an attempt was made to arrange and summarize the material collected. It was then found desirable to select a single fungicide from those which had been brought into prominence and discuss it more thoroughly than would be practicable in a publication designed to include a large number of such preparations. The fungicide selected was Bordeaux mixture, (1) because it is now used more than any other, and (2) because there can be no question that it exceeds all others in cheapness, efficacy, and harmlessness to both animals and plants. The bulletin therefore relates in the main to Bordeaux mixture, and, aside from its value to practical commercial horticulturists, will, it is believed, prove of interest to experiment station workers and others who are in position to follow up some of the lines of investigation suggested.

Respectfully,

B. T. GALLOWAY,
Chief of Division.

Hon. J. STERLING MORTON,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

U. S. Department of Agriculture,
Division of Vegetable Pathology,
Washington, D. C., October 31, 1893.

Sir: The bulletin submitted herewith is designed to show the present condition of our knowledge of Bordeaux mixture, to indicate those features which in the estimation of the writer require further explanation, and to point out certain lines of investigation likely to prove fruitful. In the bulletin is also given a list of the diseases that have been treated with the mixture, and in connection with this a discussion of the success or failure attending the treatments. In the preparation of this bulletin great difficulty was encountered, owing to the unsystematic way in which experiments have been conducted, and the ambiguous manner in which they were reported. In many cases the conclusiveness of certain experiments seemed doubtful, either from inability of the experimenters to state results clearly or from an apparent unconscious magnification of results.

It is earnestly desired that corrections and criticisms of the opinions herein advanced will be freely expressed, as the writer hopes that the value of the bulletin will be increased by the publication of such proofs as support statements which have seemed unwarranted.

I wish here to acknowledge my obligations to Dr. R. C. Kedzie, of the Michigan State Agricultural College, and Prof. J. T. Willard, of the Kansas State Agricultural College, who have greatly aided me by suggestions as to the chemical nature of Bordeaux mixture. My thanks are also due to the various members of the Division who have assisted in the preparation of the bulletin.

Respectfully,

D. G. Fairchild,
Assistant Pathologist.

B. T. Galloway,
Chief of Division.

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BORDEAUX MIXTURE AS A FUNGICIDE.

HISTORY OF BORDEAUX MIXTURE.

The name of this mixture is derived from the place of its origin, Bordeaux, France. The omission of the word "mixture" immediately following the word "Bordeaux" is not to be encouraged, and "copper mixture of Gironde" is too long a title to be easily used. In French the name is written *Bouillie bordelaise* and occasionally *Bouillies bourguignonnes;*[1] in German, *Bordeauxbrühe*, *Kupfer Kalk Mischung*, *Bordeaux Mischung*, and less correctly *Bordelasier Brühe*: and in Italian, *Poltiglia bordolese*.

The use of Bordeaux mixture originated in France, in the neighborhood of the city of Médoc, which is situated on the banks of the River Gironde. It was first used in the form of a thick paste composed of milk of lime and copper sulphate. This was sprinkled upon the vines or trellises near highways to deter boys and vagrants from pillaging the vineyards. Its conspicuousness, together with the belief that it was poisonous, did much toward rendering the remedy effective for this purpose. It is not known how long this practice had been in vogue previous to the time when Millardet, professor of botany in the faculty of sciences of Bordeaux, first brought the matter to the attention of viticulturists, but probably it had been in use for many years. In a visit to this region in 1882, Millardet was informed by the viticulturists that the portions of their vineyards which had been treated with this paste did not suffer from mildew. Although, as Millardet himself stated,[2] he had been searching for a remedy for mildew since 1878, when it was first introduced into France, he had not discovered any clue to its successful prevention, but shortly after his visit to Médoc he published what seems to be the first suggestion that the use of copper sulphate might prevent mildew.[3] In 1883 he carried on experiments to test a mixture similar to that used in Médoc, and in 1884 these were repeated upon a larger scale. Notwithstanding the fact that the experiments of 1884 were far from decisive, owing to an absence of the disease, the author communicated his results to the Society of Agriculture of Gironde, on the first of May, 1885.[1] The viticulturists at once became interested and began testing the mixture. In 1885 Millardet repeated his experiments, this time with more marked success.[2] Between 1883 and 1885 several investigators, approaching the subject from different points, published suggestions as to the possible efficacy of the salts of copper as a preventive of mildew. From a careful review of the literature, however, it appears that to Millardet is due the credit of first correctly interpreting the immunity shown by the treated vines in Médoc, and of conceiving a practical method by which copper sulphate could be used as a remedy for the disease in question.

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[1] *Gaillot.* Bouillies bourguignonnes contre le mildiou. <Jour. d'Agr. Prat., 1888, t. 1, 52^{e} ann., pp. 732–734. Claims to have used this mixture in June, 1886, before Millardet discovered it. This, however, is a mistake, as Millardet's first article was published some time previously.

[2] *Millardet.* Traitement du mildiou et du Rot. <Jour. d'Agr. Prat., 1885, 49^{e} ann., t. 2, pp. 513–516.

[3] *Millardet.* Zeit. zur Wein-Obst und Gartenbau für Elsasz-Lothringen, numeros des 1^{e} et 15 Mars, 1883. Citation in Jour. d'Agr. Prat., 1885, 49^{e} ann., t. 2, pp. 801–805 (original not seen).

That the time was ripe for the reception of such a fungicide as Bordeaux mixture is easily understood when it is remembered that the vine-growing districts of France were, one after another, being invaded by the dreaded mildew. The discovery was fully appreciated, as is evidenced by the hosts of articles which are to be found in the French agricultural and viticultural papers appearing subsequent to 1885. Much of the work since this date upon the mixture has been to discover its most economical form, the best methods for its preparation and application, and general use for the prevention of as large a number of plant diseases as possible. While to the French is due all credit for the discovery of Bordeaux mixture as a fungicide, its extension has been much more rapid in America than in any other country. It is somewhat surprising to find how comparatively little the mixture has been used in France upon other plants than the vine and potato. It seems to have been confined almost entirely to the treatment of black rot of the grape and the downy mildews. The list of diseases given in this bulletin shows better than any detailed description the wonderful extension of the use of the mixture in the United States.

FORMULAS FOR AND PREPARATION OF BORDEAUX MIXTURE.

There has existed since the first introduction of Bordeaux mixture into America the greatest confusion as to the formula for its preparation, and although the exact strength of the mixture is perhaps not a matter of primary importance it would seem that a standard of strength should be adopted. In the earliest reports of the Division a great variety of formulas were recommended, most of which were taken from the French viticultural papers. The first formula employed was very concentrated and resembled a thin paste, being applied with wisps of straw or stiff brooms. As high as 18 pounds of copper sulphate and 34 pounds of lime were used in 28 or 29 gallons of water, and the first formulas recommended in this country seem to have been of this strength.[1]

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[1] *Millardet.* Ann. d. l. Soc. d'Agr. de la Gironde, 1885, p. 73 (original not seen).

[2] For a bibliography of the history of the discovery see Millardet, Sur l' histoire du traitement du mildiou par le sulfate de cuivre. <Jour. d'Agr. Prat., 1885, 49^e ann., t. 2, pp. 801-805, where what appears to be an impartial statement of the case is to be found.

In 1888, three years after the publication of the discovery of the mixture, Millardet and Gayon[2] made a series of experiments to test several formulas for downy mildew of the grape. In these experiments the authors used 6, 3, 2, and 1 kilograms of copper sulphate, with corresponding quantities of lime in 100 liters of water, to form four formulas. These formulas are equivalent to 13.2, 6.6, 4.4, and 2.2 pounds of copper sulphate in every 26 gallons[3] of water. From their experiments the authors concluded that the weakest formula, i. e., that containing 2.2 pounds of copper sulphate in 26 gallons of water, gave nearly if not quite as good results as the stronger formulas. The recommendation of a weaker formula than that containing 6 pounds of copper sulphate was made by Scribner[4] in 1887, and no warrant exists for the claim of priority advanced by a number of experiment station horticulturists and others that the amount of copper in the Bordeaux mixture could be reduced.

From the recommendations first made by Galloway[5] of a mixture containing 6 pounds of copper sulphate and 4 pounds of lime in 22 gallons of water, it has become somewhat firmly established among horticulturists that this formula is a kind of standard, and in my own experience with fruit growers I have found it somewhat firmly fixed in their minds. In order, therefore, to establish a more uniform method of the quotation of formulas, it has been suggested by Mr. M. B. Waite of this Division, that the formula above referred to be taken as a standard to which all others should be compared, and should be called the 22-gallon formula. Any other formula when quoted should be reduced to the terms of this mixture: for example, a mixture containing 2 pounds of copper sulphate, neutralized with 1⅓ pounds of lime in 20 gallons of water, would be called a 60-gallon formula, because the amount of copper sulphate when increased to 6 pounds necessitates the use of 60 gallons of water. A 78-gallon formula would contain 6 pounds of copper sulphate in 78 gallons of water, with lime sufficient to neutralize it, if prepared according to the method described below, or 4 pounds if the old method of weighing it be followed. The advantage of this method of quoting formulas is that no effort is required to remember how much copper sulphate is employed, since it is always 6 pounds, and the statement of the number of gallons of water puts one at once in possession of the whole formula. It is hoped that this or some better system of quoting formulas will be established as a standard. The correct preparation of the Bordeaux mixture is of primary importance, and is not a difficult nor laborious operation when once understood. The ingredients are copper sulphate, lime, and water. The first precaution necessary is to secure a good quality of copper sulphate, and strong, fresh quicklime. Copper sulphate which contains a large amount of iron or zinc sulphate should not be used, although it has not been proved that the latter ingredients really injure the mixture.

---

[1] *Hilgard, E. W.* Cal. Exp. Sta., Bull. No. 51, Jan., 1886. *Riley, C. V.* Rural New Yorker, Feb. 6, 1886. *Colman, N. J.* Circular No. 1. Section of Mycology, U. S. Dept. of Agr., May, 1886. *Scribner, F. Lamson.* Ann. Rept. of the Commissioner of Agriculture for the year 1886, p. 100.

[2] *Millardet et Gayon.* Les nouvelles formules de la bouillie bordelaise. <Jour. d'Agr. Prat., 1888, t. 1. pp. 663-665, 691-694.

[3] One hectoliter of French measure is equivalent to 22 gallons of English liquid measure, and to 26 gallons of United States standard measure. The mistake of translating French hectoliters into English instead of American gallons made by Erwin F. Smith in Sec. of Veg. Path. Bull. No. 2, Appendix C, p. 65, seem to have passed unchallenged until pointed out by McCarthy in "Plant diseases and how to combat them." <N. C. Agr. Exp. Sta. Bull. No. 76, Mar., 1891, p. 6.

[4] *Scribner, F. Lamson.* Treatment of the potato and tomato for the blight and rot. <Bot. Div., Sec. of Veg. Path. Circular No. 4, July 2, 1887, p. 2.

[5] *Galloway, B. T.* Treatment of black rot of the grape. <Bot. Div., Sec. of Veg. Path. Circular No. 6, U. S. Dept. of Agr., 1888, p. 2.

Lime which is made from stone containing a large amount of clay is likely to be what is known as "dead" lime, and to contain small, insoluble granules. This kind of lime may be used, but is likely to give trouble unless the resulting milk be well strained before adding it to the copper sulphate. Lime which has been air-slaked should not be employed in any case, since its use results in injury to the foliage. The following description of the 22-gallon mixture is given as a guide for preparing this fungicide, any modifications of this formula consisting simply in diluting or concentrating the above formula:

Dissolve 6 pounds of copper sulphate (blue vitriol) in water. If hot water can be conveniently secured 6 gallons will readily dissolve 6 pounds in ten minutes; but if hot water can not be obtained, place the copper sulphate in a piece of sacking or any light cloth, and suspend it in a barrel containing 18 gallons of water so that the chemical is only a few inches below the surface of the water. In this way the sulphate will be dissolved in the course of six hours, while if the crystals are poured into the water and allowed to sink to the bottom twelve hours is hardly sufficient for their solution, unless constantly stirred, owing to the greater specific gravity of water which holds copper sulphate in solution. Slake 4 pounds of lime in a small quantity of water, adding the latter little by little, never enough to cover the lumps. A little care in slaking the lime will be more than repaid in the fineness of the milk secured, and it will be found that adding a pint of water when signs of slaking appear, and a second and third as the slaking is well under way, will result in a fine milk, with few unslaked granules. The addition of a large quantity of water at first or a too rapid addition generally results in a milk which contains a large amount of unslaked lime. When the slaking has been completed the milk should be made up to about 4 gallons with water. Pour the milk of lime into the solution of copper sulphate, straining the former through a piece of gunny sacking or a wire screen. See that the mixture is thoroughly stirred during the addition. The fungicide should be used as soon as prepared, for if allowed to stand more than six or eight hours it is not so easily kept in suspension and the mixture is not so adherent to the foliage.

There exist two principal modifications of the above method of preparing the mixture. One, referring to the addition of lime, was first suggested by Patrigeon,[1] and has since come into quite general use in America. Whether or not it is justly entitled to become a universal method has been questioned. This author does not weigh out the lime, but uses a solution (one-half saturated) of potassium ferrocyanide (yellow prussiate of potash) to test the mixture after the addition of what is supposed to be a sufficient amount of lime to neutralize the copper sulphate. A few drops of the solution are added, and if an insufficient amount of lime be present the drops as they strike the light blue mixture will turn a chocolate brown, but if enough lime has been used no color reaction takes place. The other modification, which depends in part upon that just mentioned, was, so far as I am aware, first suggested by Mr. M. B. Waite[2]. It has never been published by him, but has come into actual practice in New York State[3] through verbal recommendations of Prof. Beach and myself. The method consists in making up what may be called stock solutions of copper sulphate and lime, and employing quantities of these of which their equivalents in pounds had been previously figured out. For example, dissolve 200 pounds of copper sulphate in 50 gallons of water and each gallon will contain 4 pounds of the salt. Slake 150 pounds of lime and make up to a milk with 50 gallons of water and 1 gallon will contain 3 pounds of lime. In preparing the mixture for use 1 gallon of the stock solution of copper sulphate can be placed in 19 gallons of water and enough of the milk of lime added to neutralize it completely, as shown by the ferrocyanide test. It has not yet been clearly shown that the stock lime solution will not deteriorate upon standing, becoming the carbonate, and thus endangering the foliage by its use; but for extensive orchards this method will undoubtedly come into general use.

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[1] *Patrigeon, G.* Revue viticole. <Jour. d'Agr. Prat., 1890, t. 1. 54e ann., p. 701.

[2] Since the manuscript of this bulletin was handed in Mr. Swingle has pointed out in the Journal of Mycology, Vol. 7, No. 4, that the method of preparing stock solutions here described was suggested by Ricaud, of France, in 1887. Mr. Waite in the same number of the Journal published an account of his method in full.—(B. T. Galloway.)

[3] *Scoon, C. K.* Better than weighing Bordeaux mixture. <Allegan Gazette, Mich., May 13, 1893.

CHEMISTRY AND FUNGICIDAL ACTION OF BORDEAUX MIXTURE.

The reactions which take place when milk of lime is added to a solution of copper sulphate have been generally assumed to be simple. Millardet[1] and Chester[2] have both dismissed the matter with the statement that copper hydroxide is formed and that this is the active principle of the fungicide.

In view of the variable results which this mixture has given in the hands of different experimenters, it is a matter of primary importance that a thorough knowledge of its composition be gained. The reaction given by Chester and copied by various experiment station botanists is $CuSO_4, 5H_2O + CaO,H_2O = Cu(OH)_2 + Ca\,SO_4 + 5\,H_2O$. This reaction is the simplest which could take place between pure calcium hydroxide and cupric sulphate, but is most probably not as full a statement of the chemical changes taking place in the ordinary preparation of Bordeaux mixture as seems necessary. Although a lump of lime is not a pure oxide of calcium, and the milk resulting from its contact with water is not a pure hydroxide, yet the proportion of foreign substances is so small as to warrant us in overlooking them in this discussion.

When a lump of lime is properly slaked the CaO of which it is composed takes up water with great evolution of heat, increases in volume, and becomes the hydroxide of calcium, according to the reaction: $CaO + H_2O = Ca(OH)_2$. A comparatively small part of the hydroxide of calcium goes into solution[3] and the remaining part is suspended in the water as fine particles of the hydroxide. This mixture is called milk of lime.

Copper sulphate or blue vitriol, although often containing a small percentage of iron sulphate, is so nearly pure that it may be considered so here[4]. The crystals have the formula of $CuSO_4, 5H_2O$, and the exsiccated light green powder made by heating the crystals, $CuSO_4, 2H_2O$.

When one-half pint of milk of lime is added to 6 pounds of copper sulphate in solution in 22 gallons of water, there is formed a flocculent precipitate, sea green in color, which sinks rapidly to the bottom if allowed to stand. Upon the gradual addition of more lime the color of the precipitate slowly changes through various shades of sea green into a deep sky blue. These changes take place quite rapidly, and unless watched for will escape notice. The sea-green precipitate, closely resembling the color of cupric basic carbonate, is only formed so long as there is an excess of the cupric sulphate. As soon as enough of the lime has been added to wholly neutralize the copper sulphate the precipitate assumes a deep sky blue color. If still more lime be added and the mixture allowed to stand a few minutes the sky blue color deepens and takes a purplish tinge. The mixture now in common use in America is that in which the precipitate is sky blue. Concentration of the mixture increases the purple color of the reaction. The explanation of the changes in the precipitate is important and has not yet received the attention which it deserves. The question of the efficacy or failure of the fungicide may depend upon an understanding of these chemical reactions.

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[1] *Millardet.* Die Weinlaube, 17 Jahrg., No. 45, p. 531; No. 46, pp. 542–544; No. 47, pp. 553–555. Review in Jahresber. ü. Agr. Chem., Vol. 8, 1885, p. 221.

[2] *Chester, F. D.* The copper salts as fungicides. <Jour. of Mycol., Vol. 6, May 14, 1891, p. 22.

[3] Calcium hydroxide dissolves more readily in cold than in hot water; 100 parts of water at 15.6° C. dissolve 0.1368 part of the hydroxide and at 100° C. only 0.0752 of a part (Wettstein).

[4] *Van Slyke, L. L.* Fungicides, analysis and valuation. <Cult. and Country Gent., Albany, 1891, p. 556. Shows samples from a New York firm to be 99.6 per cent pure.

The color reactions are not confined to the combination of lime and copper sulphate, but may be produced by several of the alkalies. Prescott and Johnson[1] claim that the action of ammonium hydrate, as well as the fixed alkalies, when added to $CuSO_4$, is to throw down the basic salts if added short of saturation. If added to the point of saturation they form the hydroxide. The same authors state that an excess of the fixed alkalies does not dissolve the precipitate, but they fail to account for the formation of a much deeper blue coloration than that offered by the hydroxide. It seems to the writer that the action of calcium hydroxide may be analogous to the action of potassium or ammonium hydroxide. The difference seems to be that the solvent action of the calcium compound is much weaker than that of the potassium or ammonium. This view is further borne out by the theoretical composition of copper sulphate, which admits of the formation of basic salts.

It seems probable, then, that the first reactions which take place when milk of lime is slowly added to a solution of copper sulphate are those leading to the formation of the basic sulphates of copper. With the addition of more lime the acid radicals of the basic salts are gradually replaced by hydroxide, and when sufficient lime has been added to entirely neutralize the copper sulphate the resulting compound is a hydroxide of copper, $Cu(OH)_2$.

It is not known with certainty what compound of copper is formed which gives the purplish color to a concentrated Bordeaux mixture, in which a large excess of lime is used. In an admirable paper on the chemical composition of Bordeaux mixture Dr. Sostegni[2] has shown that in a mixture of copper sulphate and lime there exists a small amount of copper sulphate in solution, even though the mixture may be alkaline.

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[1] *Prescott and Johnson.* "Ammonium hydrate added short of saturation precipitates the pale blue basic salts; added just to saturation, the deep blue hydroxide (in both cases like the fixed alkalies); added to supersaturation the precipitate dissolves to an intensely deep blue solution." <Qualitative Chem. analysis, 4th edition. 1891, p. 87. It seems strange that the basic salt is called pale blue, for it appears to be a pure light green when well washed.

[2] *Sostegni, Lirio.* Sulla composizione chimica della cosi detta poltiglia bordolese. <Le Stazioni Sperimentali Agrarie Italiane, Vol. 19, Agosto, 1890, pp. 129–141.

This amount is greater when partially air-slaked lime is used, and greatest when the powdered or burnt lime, CaO, is added directly to the solution. This author concludes from his studies that the copper in the Bordeaux mixture exists in three forms. the basic sulphate, the hydroxide, and the double basic sulphate of copper and calcium. While I am not in a position to entirely disagree with these conclusions, it is certainly to be regretted that Dr. Sostegni was obliged to carry on his investigations with the use of limewater instead of milk of lime. The fact that no mention is made of the changes in color in the mixture corresponding with similar changes taking place when one of the alkalies proper is added to copper sulphate, also leads to the belief that he has overestimated the proportion of the basic salt present in the mixture as ordinarily prepared.

What part the varying composition of Bordeaux mixture plays in preventing the attacks of parasitic fungi has not yet been worked out, and remains a most promising field for research. Whether or not the spores of certain fungi will prove more susceptible to the basic sulphate than to the hydroxide, or *vice versa*, is yet unknown. The behavior of the basic sulphates, formed when air-slaked lime or even an insufficient quantity of properly slaked lime is employed, may offer an explanation of injuries arising from its use. I have long suspected that the small quantities of copper sulphate remaining in solution when air-slaked lime is employed in excess were not adequate to explain the serious injury often arising from treatments with the mixture so prepared. If, however, the air acts upon the basic sulphates of copper according to the reaction $2\ (Cu\ (OH)_2, CuSO_4) + CO_2 = 2CuSO_4 + Cu\ (OH)_2, CuCO_3 + H_2O$, as suggested by Prof. J. T. Willard, an adequate solution of the injury from improperly prepared Bordeaux mixture has been reached. It is evident from this reaction that there is liberated the normal copper sulphate, and this has been shown to be extremely injurious to the green parts of plants. Comparatively large quantities of this would be produced and would explain fully the corrosive action of the mixture. The point of most importance and the one which most fully corroborates this view is the tardiness with which the mixture injures the foliage. Should the injury from a carelessly formed mixture be due to the slight amount of copper sulphate present, the effect would be evident shortly after the treatment, but in cases which have come under the observation of different members of the Division of Vegetable Pathology this injury has not appeared until some time after the treatments and generally after a shower. The CO_2 of the air would act upon the basic sulphate slowly, and gradually transform it into the normal sulphate, according to the above reaction, and in the presence of moisture. This is a point which needs thorough investigation, and the writer regrets that its late discovery prevents him from attempting its solution at this time.

It is possible also that pathologists have proceeded too rapidly in recommending the use of potassium ferrocyanide in the preparation of this mixture. It has not yet been definitely settled that the mixture when prepared according to this method will not contain the basic sulphates and occasionally prove injurious. In attempting to avoid the inconvenience in the preparation of Bordeaux mixture the greatest care must be taken that its real value is not impaired. The excess of lime in the mixture instead of being an injurious element may prove most beneficial, preventing injuries from the copper salt and in other ways being of advantage.

What reactions take place when Bordeaux mixture properly prepared is sprayed on the foliage and fruits and in what manner the cupric hydroxide acts as a fungicide, are questions which do not seem to have received the attention their importance deserves. From investigations the writer has carried on relating to the action of a solution of potassium ferrocyanide on Bordeaux mixture in the wet condition and after drying, it is probable that the reactions are comparatively simple. When the mixture is properly prepared and copper hydroxide forms the preponderating copper compound in the fungicide, there is undoubtedly an excess of calcium hydroxide, which amount varies with the method of preparation of the mixture. When the potassium ferrocyanide test is used this excess is comparatively small, but when the regular formula is followed the excess is considerable.

In the preliminary experiments above alluded to, it was found that although the mixture gave no reaction for copper ferrocyanide when wet, if the precipitate is allowed to dry in air containing CO_2 or if bubbles of CO_2 are passed through it, upon the addition of a solution of potassium ferrocyanide, $K_4Fe(CN)_6$, the chocolate-red insoluble precipitate of copper ferrocyanide, $Cu_2Fe(CN)_6$, is formed. What seems to be the correct interpretation of these reactions has been suggested by Prof. Willard. His explanation is as follows: When the Bordeaux mixture is freshly prepared it contains an excess of calcium hydroxide, and all of the acid radical from the copper sulphate has been taken by the lime first added, forming calcium sulphate. If, now, potassium ferrocyanide be added, no reaction takes place, since copper ferrocyanide can not be formed in the presence of strongly alkaline bases. If, however, the mixture be exposed to air in which CO_2 is present, the calcium hydroxide is soon changed into carbonate of calcium and rendered comparatively inert. The addition of potassium ferrocyanide is consequently followed by the formation of the insoluble ferrocyanide of copper. Copper ferrocyanide can not be formed in the presence of an alkali, such as potassium or calcium hydroxide, but requires the presence of an acid to neutralize the alkali.

As to the action of CO_2 upon copper hydroxide of Bordeaux mixture when dried in the open air, our knowledge is not complete. It is highly probable, however, that no change takes place, but that it remains attached to the plant in the form of the hydroxide, ready to be dissolved slowly by the rains and dews, and to be spread by them to parts of the foliage at some little distance from the place where it originally dried. Although it has been claimed by Millardet and Gayon,[1] and others that the copper salts are absorbed by the cuticle of the leaf, the late work of Rumm[2] has thrown serious doubt upon their conclusions. My own observations have failed to confirm those of Millardet and Gayon, and the unnatural conditions under which their experiments were carried on leave ample room to doubt the applicability to the question in hand. The fact that cuticular substances which have been macerated in sulphuric acid absorb and retain considerable quantities of copper sulphate, is not proof that the normal cuticle under the conditions in which Bordeaux mixture is applied will take up the same metal from a different and much less soluble compound. The extreme tenacity with which the mixture adheres makes any positive analysis depending upon the complete removal of the mixture previous to incineration seem of doubtful value. The great difficulty of ascertaining when every trace of the copper adhering to the exterior of the treated plant has been washed off, causes me to doubt the accuracy of the analyses of Millardet and Gayon, and in the face of the directly contradictory evidence of Rumm leads to the belief that Bordeaux mixture is not absorbed by the cuticle. I can not, however, follow Rumm so far as to declare the existence of any chemical or physical stimulus which tends to increase the protoplasmic activity of the chlorophyll-bearing cells. Neither am I convinced that an actual hastening in maturity of the fruit is induced by its use. Some experiments made by the Division of Vegetable Pathology brought out the significant fact that a mixture containing no lime had no beneficial effect upon the foliage, and this adds strength to the belief that any stimulating action of the copper has yet to be proved. In discussing the action of the Bordeaux mixture upon the spores of fungi it does not seem warrantable to ascribe to it properties less understood than those of the action of metallic copper. It has long been known that water containing a very small quantity of copper in solution effectually prevents the germination of the spores of certain fungi, as well as injures the tender parts of some higher plants.[3] Bright metallic copper when brought into moist contact with the spores of some species of fungi prevents or retards their germination.

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[1] *Millardet et Gayon.* Recherches nouvelles sur l'action que les composés cuivreux exercent sur le développement du Peronospora de la vigne. <Compt. Rend., t. 104, 1887, pp. 342–344; also Jour. d'Agr. Prat., 1887, 51^{e} ann., t. 1, pp. 123–129.

Levi, A. In qual modo il rame agisca come rimedio contro la peronospora della vite. <Atti e memorie dell' I. R. Soc. Agar. d. Gorizia, Ann. 26, 1887, pp. 105–108. (Review in Just's Bot. Jahresber., 1887, No. 14, II. Abth., p. 357. Original not seen.)

[2] *Rumm.* *See* p. 27.

[3] *Prevost.* Mémoire sur la cause immédiate de la carie ou charbon des blés, 1807, cited in Compt. Rend., t. 101, 1885, p. 1224.

Millardet et Gayon. De l'action du mélange de sulfate de cuivre et de chaux sur le mildiou. <Compt. rend., t. 101, 1885, pp. 929–932.

Oliver, Paul. Les tavelures des Poiriers. <Jour. d'Agr. Prat., 1881, 45^{e} ann., t. 2, pp. 20–22.

Halsted, B. D. Notes on *Monilia fructigena* and spore germination. <Bot. Gaz.

The most probable explanation of the action of metallic copper upon the spores of fungi lies in the fact that it is not a wholly insoluble metal, and when brought in contact with water, especially water containing small amounts of ammonia or carbon dioxide, gives up a small quantity of its active substance. In what way this small amount of copper acts on the protoplasm of the germinating spore is not known with certainty, but it seems quite likely that it actually penetrates the ecto plasm and produces its poisonous action on the endoplasm of the cell itself, since it has been shown by Wüthrich[1] that dilute solutions of copper sulphate enter the protoplasmic contents of the cell and may be there detected by the use of potassium ferrocyanide. It has not yet been ascertained in what the toxic action of copper consists, but it is to be hoped that our knowledge of the matter may shortly be so extended as to make an adequate explanation possible.

Bordeaux mixture when sprayed on the green parts of plants adheres in the form of small drops, which, upon drying, deposit on the leaf minute quantities of copper hydroxide. This hydroxide gives up to any moisture upon the leaf which is necessary for the germination of the

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Vol. 16, Sept., 1891, pp. 266, 267; showing that bright metallic copper when placed in drops of water containing spores of *Monilia fructigena* prevented or hindered their germination. The spores of *Ceratocystis fimbriata* Ell. and Hals., and an undescribed species of *Glœosporium* behaved in a similar manner towards copper, as was observed by Dr. Halsted and myself in 1891. Spores sown in drops of distilled water without the presence of copper germinated abundantly. One part of copper carbonate in 46,900 of water prevented germination.

Loew, O. Bemerkung über die Giftwirkung des destillirten Wassers. <Landw. Jahrb., Bd. 20, 1891, Heft 1, p. 235. The presence of 1 part of copper in 10 million parts of water proved fatal to *Spirogyra*, causing a contraction of the chlorophyll bands.

Kudelka, F. Ueber den Einfluss der Kupfervitriollösung und die Keimfähigkeit gequellten Weizens. <Oesterr. Landw. Wochenbl., 2. Jahrg., 1876, No. 24, p. 1280 cited in Biedermann's Centralbl. f. Agr. Chem., Vol. 10, 1892-'93).

Isidore-Pierre, J. Ueber den Einfluss der Wärme und des Beizens mit Kalk und Kupfervitriol auf die Keimfähigkeit des Weizens. <Ann. Agron., Bd. 2. 1876, 2. Heft, pp. 177-181.

Haselhoff, Emil. Ueber die schädigende Wirkung von Kupfersulfat und Kupfernitrat-haltigem Wasser auf Boden und Pflanzen. <Landw. Jahrb. (Thiel), 21, 1892, Heft 1 und 2, pp. 263-276.

Reveil, P. O. Recherches de Physiologie Végétale de l'action des Poisons sur les Plantes, Paris, 1865, p. 77. The literature previous to 1865 regarding the action of metallic poisons on plants is here, in part, collected.

Phillips, F. C. Absorption of metallic oxides by plants. <Trans. Engineers' Society of West Pennsylvania, Vol. 1, 1882, pp. 280-288; also Chem. News, Vol. 46, 1882, p. 224.

Bouchardat. Recherches sur les fonctions des racines. (Cited by Reveil, *op. cit.*, p. 172).

[1] *Wüthrich, E.* Ueber die Einwirkung von Metallsalzen und Säuren auf die Keimfähigkeit der Sporen einiger der verbreitetsten parasitischen Pilze unserer Kulturpflanzen. <Zeit. f. Pflanzenkrank. (Sorauer), Bd. 2, 1892, p. 92.

spores of fungi a small amount of copper, which prevents or hinders the germination. It is not necessary to assume that the toxic action is strong enough to actually kill the spores, as in the struggle which takes place between the host and the attacking parasite possibly a slight barrier only is sufficient, especially when taken in connection with the natural barrier which the plant itself offers.[1]

The remarkable difference in susceptibility towards copper salts, which, as shown by Wüthrich, exists between the spores of different species of fungi, is so well borne out by practical tests with Bordeaux mixture that it seems highly probably that the ability to control a certain disease will vary, other things being equal, directly as the susceptibility of its spores to the action of the copper salt. Although I am inclined to agree with Wüthrich that no other metal will be likely to drive copper from the field as a fungicide, I am not at all certain that some of the organic compounds which exert such a powerful influence on plants may not be utilized to greater advantage. As yet this field remains practically unexplored.

TOXICOLOGY OF BORDEAUX MIXTURE.

After so much has been written[2] about the questionable nature of fungicides, considered from a hygienic standpoint, the matter should naturally be mentioned in this bulletin. As already shown, Bordeaux mixture, when freshly prepared, is a mixture of the basic sulphates and the hydroxide of copper, together with sulphate of calcium. The toxic properties, it is evident, reside wholly in the copper present, and contrary to opinions previously expressed by the writer and commonly held by physicians, the form in which this copper is found makes little difference as regards its toxic properties,[1] so far as animals are concerned.

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[1] *Ward, H. Marshall.* On some relations between host and parasite in certain epidemic diseases of plants. <Proc. Roy. Soc. London, Vol. 30, No. 290, pp. 393–443; see also review by W. T. Swingle in Jour. of Mycology, Vol. 7, No. 2, pp. 150–152. An admirable discussion of the complex relations existing between host and parasite, and should be consulted in this connection.

[2] *Powell, Geo. T.* The scare about sprayed grapes. <Cult. and Count. Gent., Vol. 61, Oct. 15, 1891, p. 836.

Halsted, B. D. Are fungicides abused. <Garden and Forest, Vol. 4, July 29, 1891, p. 359.

Rohart, F. La vigne, le vin, et les sels de cuivre. <Journ. d'Agr. Prat., 1886, 50^e ann., t. 1, pp. 263–264.

McCarthy, Gerald. Copper salts a possible source of danger. <Agr. Sci., Vol. 5, June, 1891, pp. 156–158. Noticed in Cult. and Count. Gent., Vol. 61, June 11, 1891, p. 477; also in Southern Planter, fifty-second year, Aug., 1891, p. 430.

Galloway, B. T. The grape scare in New York. <Ann. Report Sec. of Agr. for 1891, pp. 375–376.

Barry, W. C. Union and Advertiser, Rochester, N. Y., Jan. 27, 1892.

Fairchild, D. G. Sprayed fruit harmless. <Democrat and Chronicle, Rochester. N. Y., Feb. 1. 1892.

Galloway, B. T. Get rid of the deposit. <New York Times, Sept. 27, 1891.

Danet. Contribution à l'étude de l'emploi des sels minéraux dans le traitement de la vigne. <Bull. et Mém. Soc. d. Méd. Prat. de Paris, 1888, p. 929.

Bolle, G. Il rame nel vino proveniento da vignetti trattate col vitriolo di rame. <Atti e memorie d. Società agraria in Corz., No. 5 (1886), referred to by Mach (*see* p. 22).

While the question which it is necessary at this point to discuss is not whether copper is or is not a poison, it will add to the strength of the statements which follow to remark that the latest experiments, chiefly brought together by Dr. Tschirch, professor of pharmacy in the University of Bern, point out quite clearly that copper is not to be classed in the same category with arsenic, lead, mercury, or phosphorus. The disturbances brought about in the animal organism by the absorption of copper are only temporary, and upon the suspension of such absorption the organs soon return to their normal functions.[2] When small daily doses of copper are taken no chronic action occurs, because the metal is prevented from accumulating in injurious quantities in the liver by its elimination through the gall and the urine.[3] This latter fact is in contradiction to various reported statements, especially those of Dr. E. J. Lederlie, of the New York City board of health,[4] at the time of the New York grape scare in the autumn of 1891.

Bordeaux mixture as it is now applied to plants has been questioned from two standpoints, (1) as to the possible injurious effects upon the human system from fruit sprayed with the mixture, and (2) as to the final effect upon the soil from yearly additions of copper salt. As to its effects upon the human system, there are plainly two lines of argument, both of which point quite conclusively to the unreasonableness of the questions reached.

That we daily absorb small quantities of copper from ordinary food stuffs considered entirely wholesome, is no longer a matter of doubt- From repeated analysis it has been shown that the amounts often average 0.95 of a milligram per kilogram of food.[5]

It should be remembered that food stuffs often come in contact with copper vessels and are exposed to contamination from the dust of cupric oxide blown from the copper and brass fixtures in modern houses, and also that many of the ordinary cereals and vegetables contain, as a normal but necessary constituent, small quantities of copper. Even the leaves and fruit of the vine itself contain, as a normal but not necessary constituent of their ashes, small quantities of the chemical in question.[1] With plants, this metal can not be said to be in any sense an essential element, although. as will be mentioned shortly, plants grown in soils artificially impregnated with copper absorb the metal from such soils similarly to the way in which they absorb other non-essential elements. To illustrate the variety of plant substances which have been found to contain copper, the following few analyses may be cited:

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[1] *Tschirch, A.* Das Kupfer vom Standpunkte der Gerichtlichen Chemie, Toxicologie, und Hygiene, 1893. Stuttgart, pp. 138, p. 67 ff, and p. 105. This excellent work, which has just appeared, will be found very useful in settling numerous disputed points as to the toxicology of copper, and is heartily recommended to those practitioners who find in the presence of copper ready explanation for numerous cases of poisoning undoubtedly due to toxalbumins and ptomaines.

[2] *Tschirch, loc. cit.*, p. 106, sup. 2.

[3] *Tschirch, loc. cit.*, p. 114, sup. 5.

[4] New York Times, Sept. 27, 1891.

[5] *Tschirch, loc. cit.*, p. 138.

Copper has been detected in wine[2]; in Malaga, Catawba, and Concord grapes which had never been treated with copper mixtures;[3] in the foliage of vines gathered near Pisa, Italy, never treated with copper preparations, but dusted with sulphur;[4] in cherry brandy;[5] in olive oil;[6] in the cocoa beans (*Theobroma cacao*), both in the natural state and after roasting or drying, more particularly in the thin seed coats or shells;[7] in coffee;[8] in various cereals;[9] in potatoes;[10] in beans and carrots;[11] and in a large number of canned goods, such as apricots, gooseberries, currants, raspberries, peaches, pears, and pineapple strawberries (*Fragaria grandiflora*), which had not been subjected to the regreening process by copper sulphate.[1]

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[1] The literature of this subject has been well worked up by Dr. Tschirch in his book already cited, chapters I and II and a few of the more important references only will here be cited.

[2] *Peretti*, 1862. Cited by Tschirch, without data, and notable as being previous to the discovery of Bordeaux mixture.

[3] *Penny, C. L.* Several articles of food known to be healthful found to contain small quantities of copper. <Del. College Exp. Sta. Second Ann. Report, 1889, p. 173. One million parts of fresh berries contained from 1.01 to 1.29 parts of copper.

[4] *Sestini, Fausto.* Del rame che puo trovarsi nelle differ entti parti della vite. <Estratto Dagli Annali d. R. Accademia do Agricolture di Torino, Vol. 25, d. 20, Nov., 1892, p. 57. One million parts of the fresh leaves yielded 0.47 to 0.60 of one part of copper (see also *Papasogali*, Chem. Centralbl., 1888, S. 234, cited by Tschirch).

[5] *Nessler.* <Journ. de Pharm. d'Alsace-Lorraine, 1882; Journ. de Pharm. et de Chim., 1882, p. 290; Zeitsch. f. Anal. Chem., 1883, S. 33.

[6] *Braithwait.* <Pharm. Journ. and Transact., 3d ser. Vol. 18, p. 12. Cited by Tschirch.

[7] *Duclaux.* <Bull. Soc. Chim., Vol. 16, p. 35. Galippe. <Journ. de Pharm. et de Chim., 1883, p. 505; Répert d. Pharm., Vol. 11, p. 277. One million parts of the natural cocoa contained 11.2 to 28.8 parts and the same quantity of the dried or roasted cocoa yielded 14.0 to 29.2 parts of the metal, according to Galippe. Duclaux found 9 to 40 parts per million in the roasted beans and observed enormous amounts in the shells, 200 to 225 parts per million. Various other authors are quoted by Tschirch, *loc. cit.*, p. 6, as having found copper in cocoa (consult Pharm. Rundschau, 1883, S. 195; Arch. d. Pharm. (3), Vol. 16, S. 552; Pharm. Centralhalle, 1883, S. 268; Pharm. Zeit, 1883, No. 67; Jahresb. d. Pharm. 1883).

[8] *Sarzeau.* <Journ. Pharm., 1830, p. 505; Pharm. Centralbl., 1830, S. 409; Arch. Pharm., 1853, 75, S. 260, cited by Tschirch, p. 6; see also Galippe *loc. cit.*

[9] *Sarzeau.* <Arch. de Pharm., 1853, 75, S. 260; Journ. Pharm., 1832, p. 217; Pharm. Centralbl., 1832, S. 319; Journ. Pharm., 1832, p. 653; Pharm. Centralbl., 1833, S. 4. Cited by Tschirch. *Boutigny.* <Journ. de Chim. méd., 1833; Pharm. Centralhalle, 1833, S. 250. Cited by Tschirch. *Van der Berghe.* <Journ. Pharm. et Chim., 1882, p. 28 (Soc. de méd. de Gand.). Cited by Tschirch. In one million parts of grain (kind not stated) from 0.0184 to 0.0216 of a part of copper was found.

[10] *Deschamps.* <Bull. de l'Acad. de Méd., 1847, t. 13, p. 542. One million parts containing 2.8 parts of copper. Cited by Tschirch, p. 8, Sup. 3. *Neale, A. T.* Cited on p. 22 of this bulletin.

[11] *Galippe.* Cited by Tschirch, p. 8, Sup. 4.

Although the above list could be greatly enlarged and the number of analyses perhaps tripled, enough instances have been cited to show beyond question that the presence of copper in vegetable substances is more than merely occasional—it is common. As for its presence in animal substances, it will be sufficient for the present purpose to refer to a few of the host of positive analyses which have been made. Copper has been found in the feathers of an African bird, the Turaco[2]; in oysters and mussels[3]; in tunicates and fresh and salt water crabs[4]; in guano[5]; in beef liver[6]; in oxen's flesh and oxen's blood[7]; in the livers of sheep, calves, beeves, dogs, and cats; in the kidneys of beeves, sheep, and rabbits[8]; and in the flesh and liver of human beings.[9] Although in the human body and probably in any of the higher animals the copper can not be said to form a normal constituent of the animal substance, in the blood of certain invertebrates this seems not to be the case. The copper found in the blood of crustaceans, cephalopods, and gasteropods, first found by Harless[10], is, according to Fredericq[11], in the form of a copper albuminate, which he calls *hæmocyanin* and which acts as a respiratory albuminous substance like hæmoglobin.

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[1] *Mayrhofer X.* <Vers. Bayr. Chem. Augsburg, 1891, S. 81. Cited by Tschirch, p. 8. "Bezüglich der (natürlich neugekupferten) Conserven macht Mayrhofer folgende Ausgaben: Er fand im Kilogram Haselnüsse. 0.0031, Weichselkirschen, Aprikosen 0.001, Hagebutten 0.0028, Stachelbeeren 0.0042, Johannisbeeren 0.008, Pfirsiche 0.0055, Himbeeren 0.0042, Birnen 0.0042, Ananas-Erdbeeren 0.008."

[2] *Church.* Gmelins Handbuch, 4e Aufl., S. 2355; Chem. News, 1869, S. 265; Ber. d. Deutsch. Chem. Ges., 1870, S. 459. Five to 8 per cent of the coloring matter, called turacin, was found to consist of copper. Cited by Tschirch, p. 10.

[3] *Cuzent.* <Jour. f. prakt. Chem., 88, S. 446. Cited by Tschirch, p. 18. Observed by various other authors. One kilogram of oysters was found to contain 2 grams of copper (2,000 parts per million).

[4] *Hilzer.* <Ber. d. bayr. Chemiker, 1892, S. 29. Cited by Tschirch, p. 18. One million parts contained 20 parts of copper.

[5] *Wicke.* <Nachrichten d. Göttingen Ges. d. Wiss., 1864, S. 275. Cited by Tschirch, p. 18. One million parts contained 12 parts of copper.

[6] *Penny, op. cit.*, p. 273. One million parts contained 56.62 to 58.85 parts of copper.

[7] *Sarzeau, loc. cit.* One million parts contained 1 part of copper.

[8] *Lehmann.* <IX. Vers. der bayr. Chemiker in Regensburg, Vol. 9, 1892, p. 18. Cited by Tschirch, p. 18. One million parts of sheep's liver yielded 18 parts; calves' liver, 48 parts; beeves' liver, 51 parts; dogs' and cats' liver, 10 to 12 parts; and beeves', sheep's, and rabbits' kidneys, 3.8 to 8 parts of metallic copper.

[9] *Tschirch, l. c.*, pp. 18, 19. Cites 13 published cases where copper has been found in the human body in amounts varying, in the case of analyses of liver, from 1 to 295 grams in each liver, and remarks on p. 17: "Die Beobachtungen sind so zahlreich, dass ein Zweifel darüber nicht bestehen kann, dass das in der That eine ganz ausserordentliche Verbreitung besitzt."

[10] *Harless.* <Müller's Arch., 1846, p. 142, and 1847, p. 148.

[11] *Fredericq.* <Compt. rend., 1878; Bull. de l'Acad. des Sci. de Belgique, 1878, No. 2, p. 549, and 1879. See also *Krukenberg.* <Vergl. Phys. Studien, 3, 1880, p. 76; Centralbl. f. d. med. Wissensch., 1880; Gamgee, Physiological Chemistry, 1880, p. 132, where the literature is given very fully. All references from Tschirch, *op. cit.*, p. 11.

While, as remarked by McElroy,[1] the fact that copper has been found in so many plant and animal food stuffs does not prove its innocuous nature, still when taken in connection with the great dearth of evidence as to its poisonous properties and the direct experiments lately completed by Tschirch[2] upon several of the lower animals, they certainly throw the burden of proof upon those who would put copper among the really poisonous metals. The experiments above alluded to comprised feeding tests and subcutaneous injection experiments with rabbits, dogs, and frogs, and led the author to the general conclusion that the most insoluble as well as the most soluble salts of copper react alike on the animal organism. These experiments on the lower animals when taken in connection with those carried on recently by Lehman[3] upon his pupils, seem to affirm quite positively that daily doses of the various copper salts containing from 10 to 30 milligrams of copper per kilogram (10 parts to 30 parts in a million) are not likely to cause the least disturbance.

In the light of these modern views as to the toxic nature of copper, all fears can be allayed by the statement that fruit upon which Bordeaux mixture is not only plainly visible, but pronouncedly so, when subjected to analysis has been found to contain less than 50 parts of copper in a million parts of the grapes, including the stems.[4] If the skins of such heavily treated grapes are eaten, the taste of copper can be easily recognized. If the consumer will avoid eating fruits which have a pronounced copper flavor he will avoid even the fancied danger from copper poisoning, but since untreated fruit may contain the metal he will never be able to avoid the absorption of small quantities of copper in one of its various compounds.

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[1] *McElroy, K. P.* Foods and food adulterants. <Div. of Chemistry, Bull. No. 13, part 8, U. S. Dept. Agr., 1893, p. 1045. An unusually large number of analyses of vegetables are given in the bulletin, and it is worthy of note that the quantities of copper found in canned peas bought in Washington markets exceeded in nearly every case the usual amount of copper found upon treated grapes. Thirty-eight samples of French peas yielded from 15.8 to 157.7 milligrams per kilogram, and of 43 samples of American peas 29 contained copper, in 16 of which the amounts exceeded 10 milligrams, the limits being from 10.8 to 74 milligrams per kilogram. The maximum amount found upon treated grapes is 47 milligrams per kilogram of berries and stems.

[2] Tschirch, *loc. cit.*, Theil. II.

[3] Münch. med. Wochenschr., 1891, Nos. 35 u. 36. Cited by Tschirch.

[4] The literature on this part of the subject is also in part collected by Tschirch, *op. cit.* In addition to references there cited the following may be mentioned as important: *Griessmayer* (*see* p. 23). *Rossel, A.* <Jour. d'Agr. Suisse, Geneva, 1886, No. 49 (review in Just's Bot. Jahr., 1887, 2te Abth., 14, p. 358). *Mach, E.* Bericht über die Ergebniss der im Jahre 1886 ausgeführten Versuche zur Bekämpfung der Peronospora. <Tirol. landw. Blätter, 1887, VI, S. 37–53 (review in Jahrb. über d. Agr. Chem. (Hilger), 1887, p. 270). *Millardet et Gayon, loc. cit. Penny, C. L., loc. cit.* One million parts contained from 2.4 to 6.23 parts of copper. *Galloway, B. T., and Fairchild, D. G.* Experiments in the treatment of plant diseases, Part I. <Jour. of Mycol., Vol. 6 pp. 94, 95. Five parts of copper per million of grapes. *Neale, A. T.* Absorption of copper by potatoes, and copper on grapes. <Del. Exp. Sta. Third Ann. Report, 1890–'91, p. 23. Shows sprayed grapes, on which Bordeaux mixture was visible and perceptible to the taste to contain 47 parts per million. This is the largest amount reported, and the report lacks entirely in detail. *Maynard, Samuel T.* The amount of copper on sprayed fruit. <Mass. Hatch Exp. Sta. Bull. No. 17, pp. 38–40. The amount of copper from grapes badly disfigured with the Bordeaux mixture was only 20 parts of the oxide or 15.9 parts of metallic copper in one million. One peck of apples sprayed 3 times (dates not given) yielded 1.4 milligrams of copper oxide.

After what has been said it can be easily seen that the wines made from treated grapes are in no way open to suspicion. It will only be necessary here to refer to the hosts of analyses of wines which have been repeatedly and carefully made. These analyses show that the amount of copper present seldom if ever exceeds 10 parts per million, and in the vast majority of cases does not reach the insignificant amount of 1 part per million.[1]

The somewhat remarkable absence of copper from wines made from grapes heavily treated with Bordeaux mixture has been a matter of considerable discussion, and the manner of the disappearance of the copper has not been satisfactorily settled. It has been claimed by Quantin[2] that the copper salt is converted during the fermentation of the must into the sulphide, which is insoluble in the acids of the wine, and this view is partially supported by the observation of Sostegni[3] and Gayon and Millardet,[4] that the sulphur used against the Oïdium aids in the removal of the copper. It is claimed by these authors and also by Carpenè[5] that the sulphur is transformed into hydrogen sulphide during fermentation, and by its action on the copper salt which has been dissolved by the acids of the wine converts the copper into the sulphide, which is insoluble in the acetic acid of the must. It seems more probable, however, as has been pointed out by Tschirch, that the action of chlorophyll in the skins of the berries brings about, in the process of fermentation, a chemical combination with the copper. This compound of copper and chlorophyll has been called copper phyllocyanate[1] (*Kupferphyllocyanat*), and its presence in the must furnishes the best explanation which has been offered of the removal of the copper from wines made with treated grapes.

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[1] *Griessmayer.* Ueber den Einfluss des Weinstocks mit Kupfersulfat auf den Kupfergehalt der Weinprodukte. <Allgem. Brauer- und Hopffenzeitung, 27. Jahrg., 1887, No. 5, S. 57 (reviewed in Biedermann's Cent. f. Agr. Chem., 16. Jahrg., 1887, p. 573). *Millardet et Gayon.* Recherche du cuivre sur les vignes traitées par le mélange de chaux et de sulfate de cuivre et dans la récolte. <Jour. d'Agr. Prat., 1885, 49^e ann., t. 2, pp. 732–734. *Millardet et Gayon.* Effets du mildiou sur la vigne, influence d'un traitement efficace. <*Ibid.*, 1885, 49^e ann., t. 2, pp. 627–629. *Fallot, B.* Le cuivre dans les vins. <Prog. Agr. et Vit., 1889, t. 11, 6^e ann., pp. 492–496: 506–510. *Chuard, E.* Kupfergehalt von Reben, welche mit Vitriollösung behandelt wurden und Ausscheidung derselben. <Schweiz. landw. Zeitsch., 1889, Bd. 17, p. 437. (Review in Jahr. ü. d. Fortsch. d. Agr. Chem., 1889, Bd. 12, N. F., p. 267. *Frèchou.* Le black rot et les vins des vignes traitées. <Jour. de l'Agr. (Barral), 1889, 24^e, ann. t. 1, pp. 649–652. *Carpenè, A.* Il rame nel vino e nelle derrate alimentari ecc., Torino, 1890, pp. 28. *Mach, E.* Ueber den Kupfergehalt der Weine aus Weingärten, die zur Bekämpfung der Peronospora mit Kupfervitriol behandelt wurden. <Tiroler landw. Blätter, Jahrg. 5, No. 13, 1886, pp. 129–132. *Comboni, E.* Ricerche sopra uve, mosti e vini provenienti da vitigni trattati con rimedi a base di rame. <Rassegna di Vit. ed Enol., 1889, pp. 225–229.

[2] *Quantin, H.* Sur le méchanisme de la disparition du cuivre dans les vins provenant de vignes traitées par les sels de ce métal. <Jour. de l'Agr. (Barral), 1889, ann. 22, t. 1, pp. 659–663.

[3] *Sostegni, Livio.* Sulla pricipitazione del rame in mosti e vini provenienti da uve trattate con i rimedi contenente sali di rame usati per combattere la peronospora della vite. <Le Staz. Sper. Agrar. Ital., Vol. 15, 1888, pp. 25–37.

[4] *Gayon et Millardet.* Le cuivre dans les seconds vins et dans les piquettes. <Jour. d'Agr. Prat., 1886, 50^e ann., t. 2, pp. 618–619.

[5] *Carpenè, loc. cit.*, p. 14.

In conclusion, the only warning that seems necessary in the use of this mixture is to spray with care toward the time of maturation of the fruit, decrease the strength of the mixture as the season advances, and do not attempt to market badly spotted specimens.

With regard to the effects of copper sulphate on plants and soil, much has been written, and yet little is to be found in the literature really relevant to the toxic action of Bordeaux mixture. As previously explained, the mixture contains no free sulphate of copper, and hence all soil tests and experiments with sprouting seeds in which solutions of copper sulphate have been used throw little light upon the action of the fungicide in question. The investigations of Haselhoff[2] on the action of waters containing copper sulphate and copper nitrate have been cited[3] in support of the opinion that Bordeaux mixture will prove injurious to vegetation if used continuously on growing crops. As will be shown later, a close analogy does not exist between the action of easily soluble copper salts and nearly insoluble ones. Pearson[4] has gone so far as to claim that the surface-feeding weeds in treated vineyards have been affected by the copper used in spraying the vines. As no definite experiments were carried on by the author, and in view of the contradictory evidence, it seems improbable that the inferior growth of the surface weeds noticed by Col. Pearson is to be attributed to the action of Bordeaux mixture.

While the paper by Dr. Haselhoff, above referred to, mainly concerns the action of soluble copper salts, the conclusions reached as regards the action of calcium carbonate in the soil have a distinct application to the question under consideration. In his experiments the author tested the action of weak solutions of copper sulphate and nitrate upon oats. barley. and mixed grasses; and while he ascertained that solutions containing 10 : 1.000.000 of copper oxide as sulphate[1] were injurious to the roots of these plants. he also established the fact that the presence of calcium carbonate in the soil hinders the poisonous action of the solution by uniting with the copper sulphate and producing an insoluble copper compound. The analogy between the action of the highly calcareous soil of Dr. Haselhoff and the hydrate and carbonate of lime used in the preparation of Bordeaux mixture are at least suggestive. especially when it is remembered that the reaction between the lime and the sulphate has taken place before Bordeaux mixture is applied to the soil. It can not be doubted also that the excess of calcium hydrate employed is converted into the carbonate by the action of the CO_2 of the air and remains ready to counteract any tendency to a solution of the copper hydrate, or to at least perform the same office that it was found to perform in the experiments above referred to.

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[1] *Tschirch, op. cit.*, pp. 27–55. The author gives the formula of copper phyllocyanate $(C_{24}H_{27}N_2O_4)_2Cu$, and has studied it with especial reference to *reverdissage*. It is soluble in concentrated alcohol and chloroform, but insoluble in acetic and hydrochloric acid and only slightly soluble in ether.

[2] *Haselhoff, Emil.* Ueber die schädigende Wirkung von Kupfersulfat- und Kupfernitrathaltigem Wasser auf Boden und Pflanzen. <Landw. Jahrb. (Thiel), Bd. 21, 1892, Heft 1 und 2, pp. 263–276.

[3] *McCarthy, Gerald.* Copper salts a possible source of danger. <Agr. Sci., Vol. 5, June, 1891, pp. 156–158.

[4] *Pearson, A. W.* Copper salts and vegetation. <Garden and Forest, Vol. 4, Oct. 21, 1891, pp. 498–500.

In addition to the work of Dr. Haselhoff. which is in many respects the most extensive that has been published. Berlese and Sostegni.[2] Schroeder and Reuss.[3] and Pammel[4] have studied the subject without throwing any considerable light on it. The experiments of the first four authors mentioned confirm those obtained by Haselhoff in showing the great absorptive and neutralizing power of soils towards copper sulphate: and the tests of Pammel. although not on as large a scale as could be wished. point to the innocuous nature of Bordeaux mixture on the corn plant during development, which. according to Haselhoff, is especially susceptible to the action of copper sulphate. The experiments of Beach[5] in this connection are particularly interesting, and I regret that both series have not yet been published. In the first series made in 1892 the author tested the effect of solutions of copper sulphate on the germination and growth of tomatoes. peas, and wheat in the greenhouse. As might have been expected. the solution seriously injured the plants. being used in the relatively enormous quantities of 5 parts of copper sulphate to each 100 parts of soil. While the seeds uniformly germinated more quickly, the plants were greatly stunted, and ripened their fruits prematurely whenever any were formed. The tomato plants also absorbed large quantities of the copper, 608 parts per million of the dry substance. In a subsequent series of experiments which I had the pleasure of examining personally, and through the kindness of Prof. Beach have the privilege of mentioning, the plants were grown in soils containing large amounts of Bordeaux mixture. The effect of the mixture was very striking, but to the surprise of both Prof. Beach and myself it had a beneficial rather than deleterious action. The plants grown in soils containing Bordeaux mixture were large and better developed than those grown in check soils. Jones[1] records a beneficial effect from a six hours' emersion of seed corn in an 11-gallon formula of the mixture, and the experiments of Kellerman[2] upon the treatment of wheat smut with Bordeaux mixture point to the innocuous action of the mixture upon the seeds of cereals.

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[1] Equivalent to 31.49 milligrams of copper sulphate crystals ($CuSO_4$, 5 H_2O) in 1 liter of water.

[2] *Berlese. A. N., ed Sostegni. L.* Osservazioni sull' idea di preservare le vite dal invasione della Peronospora mediante la cura interna preventiva con solfato di rame. <Staz. Sper. Agr. Italiene. Vol. 21, 1891, pp. 229–233.

[3] *Schroeder, J. von, und Reuss. C.* Die Beschädigung der Vegetation durch Rauch und die Oberharzer Hüttenrauchschäden. <Unter Beihülfe d. Kgl. Preuss. Minist. f. Landwirth. Domanen u. Forsten, 4 , 333 p., und Anhang. Berlin 1883 (review in Bot. Centralbl.. 1883. Bd. 16, p. 368; original not seen).

[4] *Pammel, L. H.* The effect of fungicides on the development of corn. <Agr. Sci. Vol. 6, 1892. pp. 217-220.

[5] *Beach, S. A.* Copper soils and vegetation. <Cult. and Country Gent.. Vol. 57, Jan. 28, 1892, p. 68. Influence of copper compounds in soils on vegetation. <N. Y. State Agr. Exp. Sta. Bull. No. 41. new ser.. Apr.. 1892. pp. 35–43.

The only conclusion which seems deducible from the experiments that have so far been made is that Bordeaux mixture has not an injurious action upon the soil and is not in any sense likely to bring about its sterility. The very fact that a quantity of lime more than equaling that necessary to neutralize the copper sulphate is added to the soil at each application of the mixture renders any serious action upon the plants quite improbable.

As to the action of Bordeaux mixture upon the green parts of plants, we are in possession of only the scantiest information. Numerous cases have been recorded of serious injury to the foliage from its use. Weed,[3] Göthe,[4] Chester,[5] and Galloway[6] have shown its occasional injurious nature. But as pointed out by Galloway and Göthe, and corroborated by a knowledge of the chemical composition of the mixture, this injury is owing to the use of air-slaked lime in its preparation. It is probable that the use of air-slaked lime not only causes injury from leaving a small amount of copper sulphate in solution, but from the formation of the basic sulphate of copper, which in itself is injurious. In the use of Bordeaux mixture prepared with freshly slaked lime it is conceivable that injury may occasionally result if the two substances are not thoroughly mixed and the solutions of copper sulphate and lime are too concentrated. In this way the excess of lime may not be brought in contact with the basic sulphate, and this latter may not be given an opportunity to be transformed into the hydroxide.[1]

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[1] *Jones, L. R.* The effect of various fungicidal treatments upon the vitality of seed corn. <Vt. Agr. Exp. Sta. Fifth Ann. Report, 1891, pp. 138–141.

[2] *Kellerman, W. A.* Test of fungicides to prevent loose smut of wheat. <Kans. Agr. Exp. Sta. Bull. No. 22, 1891, p. 84.

[3] *Weed, C. M.* A season's work among the enemies of the horticulturist. <Jour. Columbus Hort. Soc., Vol. 4., Dec., 1889, pp. 94–106.

[4] *Göthe.* Zur Bekämpfung des Apfelrostes. <Gartenflora, 1889, 38. Jahr., Heft 9, p. 241.

[5] *Chester, F. D.* A few common diseases of crops and their treatment. <Del. Agr Exp. Sta. Bull. No. 15, Jan., 1892, pp. 16.

[6] *Galloway, B. T.* Experiments in the treatment of pear leaf blight, cracking, and scab. <Div. of Veg. Path., Bull. No. 3, U. S. Dept. of Agr., 1892, pp. 39, 40.

Aside from this injurious nature of the mixture, which is easily explained, there is scattering evidence to show that besides preventing the attacks of parasitic fungi the mixture is actually a benefit to the foliage of certain plants. In a recent article by Rumm[2] it is reported that the grapes on vines treated with Bordeaux mixture in the neighborhood of Bönningheim, Würtemburg, matured two weeks earlier than those on untreated vines. The author is inclined to consider such a hastening in maturity as independent of the action of the mildew, and reports its occurrence in vineyards in which the mildew is not present. In America, however, such a hastening seems not to have been noticed, even in regions where every device for securing an early ripening is resorted to. Were such a pronounced hastening actually produced it could not have escaped the notice of the many intelligent vineyardists who have been using the mixture for years. In a series of experiments in the treatment of the black rot of the grape conducted in Virginia in 1893 not only was there no hastening of maturity, but an actual retarding influence was observed. The grapes on vines treated from one to five times with Bordeaux mixture of various strengths were at least seven days from maturity when those on untreated vines were ripe enough to market. When it is remembered that no leaf disease was present in this vineyard the evidence seems to be strongly opposed to the view that Bordeaux mixture actually hastens the maturation of grapes. Nothing of importance seems to have been observed as to its effect upon other fruits in this respect. Regarding the effect upon foliage there is evidence that leaves treated with the mixture are greener than those not so treated. I can not, however, agree with Rumm that enough evidence has been brought together to show that the mixture acts as a chemical stimulus, tending to the increase in size of the chlorophyll-bearing cells. Further, that the copper itself is the active element seems to be improbable, since the action of copper sulphate or any of the other copper compounds so far employed is rather to injure the foliage than to assist it in assimilation.[3] The work of Cuboni[4] seems not to have been noticed by this author, and points out a line of investigation which deserves attention. Cuboni's experiments show that a thin coating of lime spread upon the leaves of the vine increases the nightly transpiration and tends to decrease the fluctuations between daily and nightly transpiration. The excess of lime in Bordeaux mixture quite probably produces the same effect as when lime is used alone, and offers a more promising field of investigation than that suggested by Rumm. From my own observations on the effect of various insoluble copper salts on the foliage of the pear I am not inclined to the opinion that the explanation of Rumm is conclusive, but, on the contrary, am more of the belief that it is only the mixtures containing lime which have a stimulating effect on the foliage. That the whole matter needs a thorough investigation is evident, and such studies, as well as those relative to the reported[1] increase in amount of sugar produced as a result of treatment, promise to yield valuable results.

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[1] *Sostegni* has shown that the basic sulphate is present in Bordeaux mixture as ordinarily formed (*see* discussion of the chemistry of this mixture on p. 12 *et seq*).

[2] *Rumm, C.* Ueber die Wirkung der Kupferpräparate bei Bekämpfung der sogenannten Blattfallkrankheit der Weinrebe. <Ber. d. Deut. Bot. Ges., Bd. 11, Heft 2, 1893, pp. 79–93; *Ibid*, Heft 7, pp. 445–452. *See also* adverse critical reviews by *Zimmermann* in Bot. Centralbl., 1893, No. 23, p. 308; Nos. 29, 30, pp. 119, 120; and *Aderhold* in Bot. Zeit., No. 11, 1893, p. 162.

[3] The reported cases of injury from the use of copper sulphate are exceedingly numerous.

[4] *Cuboni, G.* La transpirazione e l'assimilazione nelle foglie trattate con latte di calce. <Malpighia, Ann. 1, fasc 8.

BORDEAUX MIXTURE COMBINED WITH INSECTICIDES.

As first pointed out by Weed,[2] the arsenites can be added to Bordeaux mixture with considerable advantage. Instead of making separate applications with the insecticide and fungicide, the two substances are mixed together and the same end accomplished with one treatment. The advantages of such a combination are too evident to be dwelt upon here, except that attention should be called to the action which the lime in Bordeaux mixture has in preventing the injury so common from the use of the arsenites. In this respect the benefits from the combination even exceed those anticipated by its originator. It has been discovered by Kilgore,[3] and corroborated by Van Slyke, that the soluble arsenic (As_2O_3) which in Paris green comes from the arsenite of copper, and in London purple from the arsenite of rosanaline, is rendered insoluble by the action of milk of lime, and in this way innocuous to the green parts of plants. These same authors have shown that Bordeaux mixture has essentially this effect, and that either insecticide can be used of a much greater strength when employed with Bordeaux mixture than alone. At the rate of 1 pound to 100 gallons of the mixture no injury resulted in the experiments of Kilgore; and Gillette[1] reports the use of 1 pound in 50 gallons as causing no injury to peach or plum foliage. Various other investigators have studied the matter, and in consequence there is now considerable literature bearing upon the subject.

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[1] *Millardet et David.* Résultats de divers procédés de traitement sur le développement du mildiou. <Jour. d'Agr. Prat., 50^e ann., t. 2, 1886, pp. 764–770, 831–836, 874–878.

Girard, Aimé. Destruction du Peronospora schachtii de la betterave a l'aide des composés cuivriques. <Jour. d'Agr. Prat., t. 2, 55^e ann., 1891, pp. 15, 16. The author shows that beets attacked by the parasite and given a curative treatment did not attain normal size, but had their sugar content considerably augmented.

Müntz, A. Sur le traitement du mildiou par le sulfate de cuivre. <Compt. Rend., No. 18, Nov. 2, 1885, pp. 895–897. Sulphate of copper, 5:100, was used alone, and seemed to increase the per cent of sugar, but injured the foliage.

[2] *Weed, C. M.* On the combination of insecticides and fungicides. <Agr. Sci., Vol. 3, Oct., 1889, pp. 263, 264. To Col. A. W. Pearson is due the credit of suggesting a similar combination in his report to the Section of Vegetable Pathology. in Bull. No. 11, 1890, p. 49, which was submitted for publication in the fall of 1889.

[3] *Kilgore, B. W.* Combination of arsenites with fungicides. <N. C. Agr. Exp. Sta. Bull. No. 77*b* (Technical No. 2), July 1, 1891, pp. 8–11.

It must be remembered, however, that the compounds of arsenic can not be added with perfect impunity to a fungicide like Bordeaux mixture when it is intended for use immediately preceding the ripening of the fruit. While it has been clearly shown that the arsenites as usually applied are washed or blown away long before the treated fruit is marketed, this must in large part be explained by the nature of the compounds. Both are applied in the shape of fine, insoluble powders, which are merely suspended in the water. Upon the evaporation of the water the powders remaining readily dry, and are blown away by the wind or washed off by the first heavy rain. When they are added to the Bordeaux mixture, however, this is not the case, for, as is well known, this mixture is remarkably tenacious, often remaining attached to the fruit through rain storms of long duration and seldom becoming light and powdery enough to be blown away by the wind.[2]

This adhesive nature of Bordeaux mixture renders it highly probable that any insoluble arsenites which may be added to it will remain on the fruit as long as any traces of the mixture itself remain. It is to this phase of the question that it has seemed necessary to call attention. The bearing of these facts, which I believe has not heretofore been clearly pointed out, makes a thorough investigation of the subject from this new point of view seem necessary. Until such investigations shall have been completed the unrestricted recommendation of the combination must be looked upon as reprehensible.

Mention should perhaps be made here of the Cornell mixture, which has been prepared by Slingerland.[3] This differs from a similar mixture proposed by Brunk,[4] in that the ingredients are kerosene emulsion,[5]

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[1] *Gillette, C. P.* Experiments with arsenites (combining arsenites with fungicides). <Iowa Agr. Exp. Sta. Bull. No. 10, 1890, pp. 416–418.

[2] The only analysis which seems to have been made of fruits treated with this combined fungicide and insecticide is that reported by S. T. Maynard. <Mass. Hatch Exp. Sta. Bull. No. 17, 1892, pp. 11–18. One pound of Paris green was used to 200 gallons of the mixture, and not a trace of arsenic was found on one peck of apples sprayed three times early in the season. <*Ibid.*, p. 40.

[3] *Slingerland, M. V.* The Cornell mixture. < Science. Vol. 22, Aug. 25, 1893, pp. 105, 106.

[4] *Brunk, T. L.* Spraying experiments. < Md. Agr. Exp. Sta. Fourth Ann. Rept., 1891–'92, p. 386.

[5] Formula, $\frac{1}{2}$ pound hard or soft soap dissolved in 1 gallon of boiling water and 2 gallons of kerosene added. The whole mixture is churned with a force pump until of a creamy color and consistency.

Paris green (1 pound to 100 gallons or any strength desired), and Bordeaux mixture[1], instead of the emulsion[2], Paris green, and copper carbonate. As shown by the originator, the mixture has not proved a practical success, owing to its poor wetting quality.

EFFECTIVENESS OF BORDEAUX MIXTURE AS A FUNGICIDE.

Beyond question, Bordeaux mixture is the most effective remedy yet discovered for fungous diseases of plants. Many of the ammonium cupric compounds which have been tested, while exceeding it in ease of preparation and inexpensiveness, do not equal it in effectiveness, and produce, almost without exception, deleterious effects upon the foliage of the treated plants. While with many, a slight scorching or discoloring of the foliage may not appear to be a serious objection to a given fungicide, in the estimation of the writer no fungicide will ever come into general use which in any way interferes with the normal carbon assimilation and active transpiration of the plant. It is an imperfect fungicide in this respect, and will sooner or later be superseded by one which while preventing the attacks of parasitic fungi will in no way injure the plant. Bordeaux mixture combines these two qualities in the highest degree, preventing most effectively the entrance of the parasite without injuring the plant. Notwithstanding the remarkable effectiveness of the mixture, however, there are many diseases which have not yet been successfully combated by its use. To assume that it is a panacea for all the fungous diseases of plants before sufficiently extensive experiments have been made, is to subject one to the severest criticism and retard the legitimate extension of its use. It must, I think, be confessed that the prevailing opinion as to the all-sufficiency of this mixture does not rest upon a large enough number of experiments, and years of patient work will be required to establish or disprove all the claims that have been made for it. In the following pages I have endeavored to give the conclusions which seem warranted in regard to the diseases treated with Bordeaux mixture.

DISEASES TREATED WITH BORDEAUX MIXTURE.

DOWNY MILDEW OF THE GRAPE.

(*Plasmopara viticola* (B. & C.) Berl. & De Toni).

Bordeaux mixture is unquestionably a specific for this disease, as evidenced by many well-conducted experiments in France, Italy, and

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[1] Formula, 6 pounds of copper sulphate fully neutralized with lime, as indicated by the potassium ferrocyanide test, and the whole made up to 40 gallons with water.

[2] Formula, 27 ounces Lenox soap in 3 gallons hot water, to which 1 pound of copper carbonate and 2½ ounces of Paris green are added, and, after mixing, 6 quarts of kerosene added.

Germany, and by eight years of practical use in the vineyards of these countries and in America.[1] The use of this remedy for mildew has been made obligatory in Savoy, France, and Lausanne, Switzerland.[2] Although various other remedies have been used with success against this disease, still, when compared with Bordeaux mixture they have shown themselves inferior.[3]

The 78-gallon formula was used with success by Millardet and Gayon[4] in 1888 and Mach[5] in 1889, but from experiments made in 1892 Millardet and Gayon decided that it was too weak to prevent severe attacks. The 60-gallon formula is undoubtedly preferable.

The number of treatments necessary will depend very largely upon the season and locality, but four applications, begun with the first opening of the leaf buds and distributed about equally through the season until danger from the disease is past, are almost certain to afford full protection. With rapidly growing cuttings or young plants, treatments must be repeated as often as sufficient growth is made to expose any considerable quantity of young leaves to infection. The green parts should be kept covered.

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[1] The presence of both black rot and downy mildew in many American vineyards, and the greater severity of the former, makes it difficult to separate the experiments upon mildew from those on black rot. The experiments of Holladay, at Eastham, Va., are among the most clearly defined of American experiments, showing an undoubted success from five applications begun ten days before blooming. <Div. Veg. Path., U. S. Dept. of Agr., Bull. No. 11, 1890, pp. 70–76; *see also* Jaeger's report in Bull. No. 10, *ibid.*, 1889, pp. 29–34.

[2] *Ceriis, A. de.* Traitement obligatoire des Vignes contre le mildiou. <Jour. d'Agr. Prat., 1891, t. 2, 55e ann., pp. 39–41; *see also* note in Chron. Agr. et Vit., May 4, 1889, quoted by Galloway in Jour. of Mycol., 1889, Vol. 5, p. 95, showing penalty $2 to $18.

[3] *Mach, E.* Bericht über die Ergebnisse der im Jahre 1886 ausgeführten Versuche zur Bekämpfung der Peronospora. <Tiroler Landw. Blätter, 1887, 6. Jahrg., No. 5, pp. 37–46; No. 6, pp. 53–62.

Millardet et Gayon. Nouvelles observations sur l'efficacité de diverses bouillies dans le traitement du mildiou-sulfostéatite. <Jour. d'Agr. Prat., 56e ann., t. 1, No. 7, Feb. 18, 1892, pp. 231–239.

Millardet et David. Résultats de divers procédés de traitement sur le développement du mildiou. <Jour. d'Agr. Prat., 1886, 50e ann., t. 2, pp. 764–770, 831–836, 874–878.

Freda, Pasquale. Sui più efficaci rimedi contro la peronospora della vite. <Le Staz. Sper. Agr. Stazione, Vol. 14, fasc. 2, 1888, pp. 309–311.

Cugini, Gino. Relazione al ministero intorno di rimedi usati nel 1889, nel Modenese contro la peronospora della vite. <Bolletino d. R. Stazione Agr. d. Modena, nuova serie, Vol. 9, 1889, pp. 140–146.

[4] *Millardet et Gayon.* Les nouvelles formules de la bouillie bordelaise. <Jour. d'Agr. Prat., 1888, t. 1, pp. 623–627, 663–665, 691–694.

[5] *Mach, E.* Ueber die Bekämpfung der Peronospora. <Tirol. Landw. Blätter, 1889, 8, p. 65. Review in Jahr. d. Agr. Chem., 1889, n. f., Vol. 12, p. 266. Original not seen.

BLACK ROT OF THE GRAPE.

(*Guignardia bidwellii* (Sacc.) Viala and Rav.)

Although more difficult to prevent than downy mildew, this disease has yielded to careful treatment with Bordeaux mixture, begun before vegetation starts in the spring and continued until the fruit begins to ripen in midsummer. That treatments before the opening of the buds are necessary was shown early by the failure of the first attempts made in America by Jaeger, Munson, Lyman, and Pearson.[1] The first really successful treatments seem to have been made by Prillieux.[2]

No other fungicide seems equal to Bordeaux mixture in efficacy in the treatment of this disease, and although it has been shown by de l'Ecluse,[3] Galloway,[4] and others that a 60-gallon formula of the mixture is often fully as effective as a 22-gallon formula, in severe attacks the stronger formula has generally given the best results.[5] The number of treatments necessary varies with the season, but in no case is it safe to give less than three. The first one should always be made immediately previous to the swelling of the buds in the spring, followed by a second treatment when the leaves are about one-third grown, and the third immediately previous to blooming. The subsequent treatments should be made at intervals of from twelve to fourteen days, but judgment should be exercised as to the number and frequency of these applications. In dry weather frequent treatments are not necessary, while in wet weather applications of the mixture must be made as often as it is washed off the vines. Although the great damage done by the parasite is in its destruction of the fruit, one of its forms lives on the foliage and does considerable injury, and hence the necessity of treating the foliage as well as the fruit. The suspicion also that the form upon the leaves communicates the disease to the fruit, although not substantiated by careful experiments, emphasizes the necessity of treating both foliage and fruit. The danger of spotting the clusters from late treatments may be avoided either by making the last two treatments with ammoniacal copper carbonate solution or with an 80-gallon formula of Bordeaux mixture.

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[1] See reports of these writers on experiments made under the supervision of the Section of Vegetable Pathology in Bull. No. 5, 1888, entitled "Report on the Experiments made in 1887 in the treatment of the Downy Mildew and the Black Rot of the Grape Vine."

[2] *Prillieux.* Efficacité de la bouillie bordelaise contre le black rot. <Jour. d'Agr. Prat., 52^{e} ann., t. 2, 1888, pp. 193–195.

[3] *l'Écluse, A de.* Traitement du black rot. Rapport à M. le Ministre de l'Agriculture. <Bull. du Comité d'études et de vigilance du Lot-et-Garonne. (Reprinted in full in Prog. Agr. et Vit., 6^{e} ann., t. 12, Oct. 13, 1889, pp. 287–296).

[4] *Galloway, B. T.* Experiments in the treatment of black rot of the grape. <Div. of Veg. Path. Bull. No. 3, 1892, pp. 9–31.

[5] *Dubor, G. de.* La lutte contre le black rot. <Jour. d'Agr. (Barral), 1889, 24^{e} ann., t. 2, pp. 609–611.

Owing to the severity of the disease, great care should be taken in the application of the mixture and the selection of a suitable spraying nozzle. So far as the observation of members of the Division goes, the Vermorel nozzle is superior to any other for this purpose. A powerful pump can not be too strongly insisted upon.

The thousands of grape growers in France and America who are combating this disease every year with success, in addition to the experiments of Galloway, Chester, Clark, Thaxter, Prillieux, Alwood, and others, which have been nothing short of conclusive, furnish overwhelming evidence of the efficacy of the mixture.[1]

POWDERY MILDEW OR OÏDIUM OF THE GRAPE.

(*Uncinula necator* (Schw.) Burrill.)

While it has been the opinion of many viticulturists that Bordeaux mixture is a preventive of this disease, there seems to exist almost no literature in support of this view. This lack of literature, however, is probably owing to the comparatively small amount of damage caused by the fungus in this country. Scribner[2] says that "whether there are any remedies that will act as preventives is not known;" and in 1888 J. G. Justice,[3] of Marcus, Ga., reports vines treated with Bordeaux mixture once as being "nearly exempt from the fungus." In a report made to the Section of Vegetable Pathology in 1889, F. S. Earle[4] states incidentally that a single Black Hamburg vine which had been treated with both Bordeaux mixture and eau celeste "was very bright and green, while some Muscats and Tocays at a neighbor's were being considerably injured by powdery mildew." It is evident from the French literature that Bordeaux mixture is not considered a specific for the powdery mildew, as both sulphuring and spraying are considered necessary. M. P. Hoc,[5] in an experiment, the details of which are not fully given, reports the successful use of Bordeaux mixture against both Oïdium and downy mildew, but no care is taken to distinguish between the injury from the different species, and this makes the experiment of little value. In 1888 M. Huet[1] proposed mixing sulphur with Bordeaux mixture to prevent downy and powdery mildew at the same time. This was tested the following year by M. Martin,[2] but without success, the efficacy of the sulphur being greatly diminished. It is evident from the scanty literature on the subject that although the prevailing opinion is sufficient to warrant recommending Bordeaux mixture, there seem to be no carefully conducted experiments on record which will fully prove it.

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[1] The literature upon this part of the subject has already become stupendous and can not be cited here. *Galloway, B. T.* Summary of volunteer reports on vine diseases. <Sect. Veg. Path. Bull. No. 11, 1890, pp. 8–22; and *Scribner, F. L.* Volunteer reports on the treatment of the downy mildew and black rot in 1887. <Sect. Veg. Path. Bull. No. 5, 1888, pp. 39–71, should be consulted as giving the best collection of opinions from practical vineyardists in regard to its use.

[2] *Scribner, F. Lamson.* Report on the fungous diseases of the grape vine. <Sect. Veg. Path. Bull. No. 2, 1886, p. 26.

[3] *Scribner, F. Lamson.* Report on the experiments made in 1887 in the treatment of the downy mildew and the black rot of the grape vine. <Sect. Veg. Path. Bull. No. 5, 1888, p. 48.

[4] *Earle, F. S.* Report on experiments with fungicides. <Sect. Veg. Path. Bull. No. 11, 1890, p. 86.

[5] *Hoc, P.* Essais comparatifs de traitements contre le mildiou et l' oïdium. <Jour. d'Agr. (Barral), 24^e^ ann., t. 2, 1889, pp. 821–826.

ANTHRACNOSE OF THE GRAPE.

(*Glœosporium ampelophagum* (Pass.) Sacc.)

Although several unsystematic attempts[3] have been made to control this disease by the use of Bordeaux mixture, as far as the writer is aware, no careful experiments have ever been conducted. The difficulty of securing a vineyard badly enough infected, and in which new vines not yet attacked are growing, has so far evidently deterred investigators from taking up the matter. The many curative treatments of vines already attacked which are reported, do not seem to me conclusive, inasmuch as they all lack the presence of proper control vines.[4]

PEAR LEAF BLIGHT.

(*Entomosporium maculatum* Lév.)

This disease, which attacks young trees in nursery rows in the North and both young trees and bearing ones in the South, has received considerable attention. The experiments in which Bordeaux mixture have been used have been almost uniformly successful, and there can no longer be room for doubt that this preparation, when properly applied, is a specific for the disease.

The first systematic experiment in the use of Bordeaux mixture for pear leaf blight was made by Galloway[5] in 1889. The same year Pearson,[6] of New Jersey, acting under the direction of the Section of Vegetable Pathology, sprayed three bearing pear trees with the fungicide, the result being markedly successful in each case. The later experiments of Galloway and Fairchild,[1] and those of Chester,[2] as well as the practical use of the fungicide by orchardists and others, confirm the results of the investigations. The ammoniacal solution, modified eau celeste, copper acetate, precipitated carbonate of copper, copper sucrate (improperly called saccharate), copper chloride, sodium hyposulphite, and potassium sulphide have all been tested in comparison with Bordeaux mixture, and while showing results in some respects excelling it, they have uniformly proved slightly injurious to the foliage, while Bordeaux mixture, when properly prepared, has exhibited no injurious action. This superiority of Bordeaux mixture is to the writer's mind of the greatest importance and warrants the discarding of the other fungicides.

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[1] *Huet, D. G.* Le soufre et la bouillie bordelaise. <Jour. d'Agr. (Barral), t. 1, 23^e ann., 1888, pp. 702–705.

[2] *Martin, Louis de.* Oïdium et mildiou. <*Ibid.*, 24^e ann., t. 2, 1889, pp. 851–855.

[3] *Howell, A. M.* [Report on fungous diseases of the grape and tomato.] <Sec. Veg. Path. Bull. No. 11, 1890, p. 58. Reports "undoubted success." The lack of control vines, however, renders the work of little value.

[4] *Coste, H.* Instruction pratique sur les traitements à effectuer, contre le mildiou et l'anthracnose. <Ann. Soc. d'Hort. et d'Hist. Nat. de l'Hérault, 2^e. sér., t. 23, 1891, pp. 178–182. States that no radical remedy is known for this disease.

[5] *Galloway, B. T.* Experiments in the treatment of pear leaf blight and apple powdery mildew. <Sec. of Veg. Path. Circular No. 8, 1889.

[6] *Pearson, A. W.* Report of Col. A. W. Pearson. <Sec. of Veg. Path. Bull. No. 11, 1890, p. 46, pls. v, vi.

In the experiments of Galloway in 1891 the use of a formula equivalent to 6 pounds of copper sulphate in 180 gallons of water proved quite efficacious, and in 1890 three treatments were found sufficient to prevent the disease. The experiments of M. B. Waite, carried on in 1892 and 1893, are quite conclusive as regards the treatment of the disease in Virginia. The general conclusions that may be drawn from this work are that in the first season's trials five treatments with a 50-gallon formula of Bordeaux mixture proved entirely successful, while the second year's work showed that two treatments, the first made between May 15 and June 1, and the second one month later, with the same formula, leave nothing to be desired.

When it is remembered that these experiments were carried on in a region where the disease is usually so severe that the untreated trees are defoliated as early as July, the conclusiveness of the experiments can not be doubted.

Notwithstanding all the work that has been done on this important disease, no evidence seems to have been collected which would show an actual increase of wood production in bearing trees as a result of maintaining the health of the foliage. Neither has an increased fruitfulness of the trees been proved, as in the case of treatment of the same disease on the quince. It is to be hoped that this important part of the subject will ere long receive the attention which it deserves.

From the increased growth which young trees have been enabled to make under treatments with this mixture, it is presumable that the benefits resulting from the treatments of bearing trees are very great.

As has been pointed out, the first attempts to prevent the attacks of the disease upon young trees in nursery rows, were made by Galloway.[3] The preliminary experiment was made upon a block of French pear seedlings, and while the controls were not as near the treated portion as might have been desired, the striking nature of the results was sufficient to induce the owner to continue the treatments the following year. From the subsequent experiments carried on by Galloway[1] and the writer[2] in Maryland and New York, together with those of Pammel[3] in Iowa, it may be stated with confidence that Bordeaux mixture has proved a specific for this disease on young trees, and can be recommended for nursery practice. In those cases where the mixture has been brought into comparison with such of the copper compounds as ammoniacal solution it has invariably proved itself superior.

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[1] *Galloway, B. T. and Fairchild, D. G.* Experiments in the treatment of plant diseases. <Jour. of Mycol., Vol. 6, Apr. 30, 1891, pp. 137–142. *Galloway, B. T.* Experiments in the treatment of pear leaf blight, cracking, and scab. <Div. Veg. Path. Bull. No. 3, 1892, pp. 36–47.

[2] *Chester, F. D.* The leaf blight of the pear and the quince. <Del. Exp. Sta. Bull. No. 13, July, 1891, pp. 16, pls. 2.

[3] *Galloway, B. T.* Experiments in the treatment of pear leaf blight and apple powdery mildew. <Sec. of Veg. Path. Circular No. 8, 1888, pp. 6–8.

The increase in caliper made by young pear trees on which the foliage is kept intact is considerable, as shown by the experiments in New York State, but whether or not the effects of a single year's treatment in this section will be sufficient to warrant heavy expenses in spraying has not yet been settled to my entire satisfaction. In regions where the disease is as severe as it is in Maryland there can scarcely be a question, and the testimony of the firm of Franklin Davis & Co. may be considered quite conclusive, but in regions where the disease does its damage almost wholly on stocks and seedlings, and does not attack budded stock, the profitableness of the treatments remains only partially proved. The best results have followed a use of the mixture five or six times, and the benefits of three treatments on pear stocks, begun three weeks after planting and before the leaves were fully grown,[4] proved markedly inferior to six treatments begun at the same time, but continued until the last of August. The increase of new foliage renders it essential that treatments should be continued well through the summer. A 60-gallon formula has proved entirely satisfactory, but it has been found essential that the treatments be made in the most thorough manner possible, and any failure in the application of the mixture may result in greatly diminished effectiveness of the treatments.

PEAR SCAB.

(*Fusicladium pirinum* (Lib.) Fuckl.)[5]

This destructive disease, which has been the object of much study, especially by mycologists, has yielded to treatments from various fungicides, but owing to a lack of knowledge as to the life history of the parasite causing it, many failures have been reported in its treatment.

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[1] *Galloway, B. T.* Treatment of diseases of nursery stock. <Div. of Veg. Path. Bull. No. 3, 1892, pp. 47–60, pls. IV, V.

[2] *Fairchild, D. G.* Experiments in preventing leaf diseases of nursery stock in western New York. <Jour. of Mycol., Vol. 7, pp. 240–264, pls. XXI–XXIX.

[3] *Pammel, L. H.* Treatment of fungous diseases. <Iowa Exp. Sta. Bull. No. 13, May, 1891, pp. 31–51, figs. 22. Treatment of some fungous diseases; experiments made in 1891. <*Ibid.*, Bull. No. 17, pp. 20, pl. V.

[4] On the following dates in Geneva, N. Y.: May 21, June 3, June 24, for the three treatments, and the same dates with additional treatments made July 9, July 24, August 8, and August 28.

[5] *Ludwig*, in his Lehrbuch der Niederen Kryptogamen, Stuttgart, 1892, pp. 316, 317, cites the excellent work of Brefeld on a pleosporous fungus, *Venturia ditricha* forma

It will not be necessary to discuss here the use of such fungicides as the sulphides of calcium, sodium, and potassium, further than to remark that the experiments with these substances indicate at least a partial effectiveness, but in no carefully conducted experiments have they proved themselves superior to Bordeaux mixture. Although as early as 1881 Oliver[1] discovered that a solution of copper sulphate would prevent the germination of the spores, and when applied to the fruits protected them from the disease, it was not until 1886 that Bordeaux mixture was used in its prevention. Ricaud's[2] experiments, although evidently simple, indicated the beneficial effects following the use of the mixture, and are peculiarly noteworthy from the fact that they were begun early in the spring (March 31). Although the number of trees in the experiment was small, the untreated trees were arranged to bring out the comparison satisfactorily. Since this first and in many respects quite conclusive experiment was made, Goethe,[3] Chevallier,[4] Galloway and Fairchild,[5] and Mader[6] have tested the powers of this mixture as a preventive of the disease. While negative or only partially successful results have attended some of these experiments, the ignorance of the fact that the first attacks of the parasite occur before blooming, explains the failures quite satisfactorily. The early treatments have been uniformly more successful than later ones; in fact treatments begun after blooming do not seem to have yielded satisfactory results. From a clearer knowledge of the life history of

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piri Brefeld, which this mycologist found on the dead leaves of *Pyrus communis*, and which when cultivated produced fruiting hyphæ and spores resembling very closely those of *Fusicladium pirinum*. While Ludwig concludes from this work that the identity of the two species is established, I am not prepared to admit it until infection experiments have been made. As to the further identity of *F. dendriticum* and *F. pirinum*, I am not at all convinced, since my own cultures of these fungi have shown the distinct differences in spore abjunction to be constant when both species are grown upon the same substratum. I retain the old name until further researches prove the identity conclusively. (*See* Brefeld's Untersuchungen, Heft x, 1891, pp. 218–221, pl. VII.)

[1] *Oliver, Paul.* Les tavelures des poiriers. <Jour. d'Agr. Prat., 1881, 45^e ann., t. 2, pp. 20–22.

[2] *Ricand, J.* La tavelure des poires et le sulfate de cuivre. <Jour d'Agr. Prat., 50^e ann., t. 2, 1886, p. 922; *see also Ibid.*, pp. 719, 720, where article by Prillieux relative to this experiment is quoted.

[3] *Goethe, R.* Zur Bekämpfung des Äpfel-und Birnenrosts. <Gartenflora, 37. Jahr., 1888, pp. 263, 264. Also see Bericht K. Lehranst. für Obst-und Weinbau für d. Jahr. 1889–'90, Wiesbaden, 1891, pp. 29, 30.

[4] *Chevallier, Ch.* Traitement de la tavelure des poires. <Revue Horticole, 61^e ann., 1889, pp. 54, 55.

[5] *Galloway, B. T., and Fairchild, D. G.* Experiments in the treatment of plant diseases, part 3. <Jour. of Mycol., Vol. 6, Apr. 30, 1891, p. 142.

[6] *Mader.* Die Obsternte des Jahres 1892 und die Anwendung des Kupferkalkes gegen die Pilzschädlinge der Obstbäume. <Tiroler Landw. Blätter, 12. Jahrg., No. 3, 1893, pp. 25–28.

the fungus, and from the experiments above alluded to, it may be stated with considerable confidence, although not conclusively, that Bordeaux mixture is a specific for pear scab. In order to prove successful, however, the first application must be made immediately upon the opening of the fruit buds in spring, the second immediately before blooming, the third when the petals are falling, and the fourth when the fruit is one-half inch in diameter. These four treatments control the disease satisfactorily, and, so far as our knowledge goes, treatments made later do not increase the protection, since most varieties of pears after this time become largely resistant to the attacks of the fungus. While the stronger mixture (the 22-gallon formula) has been most generally recommended, the work of Mader showed a 75-gallon formula to give satisfactory results, but it should be given a practical test.

CHERRY LEAF BLIGHT.

(*Cylindrosporium padi* Karst.)

Although this disease is common to both bearing and young trees, as well as to stocks and seedlings, its principal injury is done to the seedlings or to the trees before they are 3 years old. The principal experiments which have come to my notice were upon young plants, although Thaxter[1] reports success from its use upon bearing trees.

The first attempt to control the disease was made by Galloway.[2] The results of these first experiments, although highly encouraging, have not been published in full. In 1890 Pammel[3] conducted a series of experiments on the same disease, from which it was evident that the benefits arising from seven treatments with Bordeaux mixture (22-gallon formula) were not great. The same author repeated his experiments in 1891, with somewhat more decided results. The later work of Galloway[4] at Mullikin, Md., and my own experiments at Geneva, N. Y.,[5] have thrown considerable light upon the problem, and it may be stated conservatively that Bordeaux mixture is a specific for cherry leaf blight of nursery stock. The treatments, however, need to be made with a carefulness exceeding that necessary in the treatment of such diseases as those caused by the downy mildews. Owing to the continuous growth of young trees or seedlings, treatments must be continued until all danger from the disease is past, as otherwise the young foliage constantly being formed will remain unprotected. The dates upon which applications should be made vary greatly, and depend upon the nature of the season, a wet spring bringing on the disease later than a dry one. Not enough experiments in different localities have been carried on to make it possible to give any but general directions in the matter. The best results were obtained from treatments which were begun in the spring immediately after the foliage was fully formed, and continued at intervals of two weeks until six treatments were made. A 60-gallon formula has proved perfectly satisfactory, but it was found absolutely necessary to have the spray reach the under sides of the leaves. The disease is a difficult one to cope with, and too great care can not be taken in the application of the fungicide. Only extensive field practice will settle the true economic value of the treatment, but it will require little argument to convince the nurseryman that stocks upon which the leaves are kept intact will make more valuable trees than those from which the foliage drops in July or August. Bordeaux mixture is undoubtedly superior to ammoniacal solution in the treatment of this disease, as is shown by the many comparative tests which have been made.

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[1] *Thaxter, Roland.* Leaf spot of plums and cherries, causing defoliation. <Conn. Exp. Sta. Fourteenth Ann. Rept. (1890) 1891, p. 24.

[2] *Galloway, B. T.* Treatment of pear, cherry, and strawberry leaf blight as affecting nursery stock. <Ann. Rept. Sec. of Agr. for 1890 (1891), p. 396. Experiments were inaugurated in 1889.

[3] *Pammel, L. H.* Treatment of fungous diseases. <Iowa Exp. Sta. Bull. No. 13, May, 1891, pp. 31–51; also Iowa Exp. Sta. Bull. No. 17, for account of further experiments.

[4] *Galloway, B. T.* Treatment of diseases of nursery stock. <Div. of Veg. Path. Bull. No. 3, 1892, pp. 47–60. This includes an account of my own work at Geneva, N. Y., for 1891, as well as the work at Mullikin, Md.

[5] *Fairchild, D. G.* Experiments in preventing leaf diseases of nursery stock in western New York. <Jour. of Mycol., Vol. 7, May 15, 1893, pp. 240–262, plates XXI–XXIX; *see also* N. Y. Exp. Sta. Tenth and Eleventh Ann. Repts., 1892 and 1893, and Ann. Rept. Sec. of Agr. for 1891, p. 368.

PLUM LEAF BLIGHT.

(*Cylindrosporium padi* Karst.)

The injury from this disease is equally severe upon bearing as well as upon young trees and seedlings, but the experiments which have been conducted show it to be amenable to treatment.[1]

The treatments of nursery stock liable to the disease have generally been carried on at the same time as those made in the treatment of cherry leaf blight, and the results have been similarly encouraging. For instructions as to the treatment of the disease in the nursery the reader is referred to the discussion of cherry leaf blight. Only applications of the fungicide which are made with thoroughness can be expected to yield satisfactory results. As for the treatment of the parasite in its attacks on bearing trees, where it often causes heavy losses, our knowledge is far from complete. The writer's experiments[2] at Geneva point out some of the difficulties in its treatment. The great variation in date of appearance and the remarkable dependence of the parasite on climatic conditions make a close observation of these factors of the utmost importance. Treatments made early in the season do not seem capable of preventing the attacks of the parasite when it appears late in the summer, and it seems probable that the use of the mixture must be continued at intervals through the summer if the best results are wished, providing moist, muggy weather occurs. It must be confessed that there is a lack of sufficiently extensive experiments to make any definite recommendations possible. The use of the mixture in Geneva has been attended with only partially successful results.

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[1] The literature cited under cherry leaf blight includes much that refers to this disease as it affects nursery stock, and should be consulted.

[2] *Fairchild, D. G.* Miscellaneous work in New York State. <Div. Veg. Path. Bull. No. 3, 1892, pp. 62, 63.

PLUM LEAF RUST.

(*Puccinia pruni* Pers.)

The experiments on this disease have not been extensive. Brunk in an experiment in 1888 reported very encouraging results from the use of Bordeaux mixture, but in the printed account no details are given, and few definite conclusions can be drawn from such a report.[1] Some recent experiments by N. B. Pierce, however, show the disease as it occurs on the prune to be quite amenable to treatment with other copper solutions, and strengthens the belief that Bordeaux mixture may really prove a specific for this malady, which is especially dreaded in the South and West. As this is the first rust fungus which has really fully yielded to the preventive treatments with copper preparations, more than usually conclusive experiments are necessary to establish the efficacy of such treatments.

LEAF BLIGHT OR SPOT OF QUINCE.

(*Entomosporium maculatum* Lév.)

Although the first experiments with Bordeaux mixture as a preventive of this disease seem to have been carried on by Pearson[2] in 1889, the work of Thaxter[3] and the experiments of the writer[4] have placed the matter on a surer footing. The author's experiments carried on in 1891 were on too small a scale to be conclusive, and the results, while showing the superiority of Bordeaux mixture over several other fungicides, would not warrant its recommendation. Unfortunately the experiment was not continued a second year. The striking results of Thaxter's simple experiment continued through two years are among the most remarkable that have been obtained from the use of this mixture, and it is to be regretted that the report in which the experiments are recorded is not sufficiently explicit as to the relative fruitage of the treated and untreated trees previous to the experiment. The fruitage of two rows treated with Bordeaux mixture for two successive years, thereby keeping the foliage intact during both growing seasons, was one hundred-fold that of adjacent rows which had been left without treatment. Such a remarkable increase requires a more than usually explicit explanation, and until further experiments can be carried on along the same lines, must be considered as unique. Four to six treatments, according to the weather conditions, begun immediately after the blossoms fell and continued at intervals of fourteen days, have proved effective in preventing both the spot on the fruit and leaf blight, which are both caused by the same parasite.

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[1] *Galloway, B. T.* Bordeaux mixture for the plum leaf blight. <Jour. of Mycol., Vol. 5, Mar., 1889, p. 38. Gives an extract from a letter by Brunk on the subject of his experiments.

[2] *Pearson, A. W.* Quince diseases. <Sect. Veg. Path. Bull. No. 11, 1890, pp. 46, 47. The observation made by Pearson that the treated tree was the only one of six which fruited the season following, is significant when viewed in the light of Thaxter's experiments.

[3] *Thaxter, Roland.* Some results from the application of fungicides. <Conn. Exp. Sta., Fourteenth Ann. Rept. for 1890, 1891, pp. 21–22. Further results from the application of fungicides to prevent the "spot" of quince. <*Ibid.* for 1891, 1892, pp. 150–152.

[4] *Fairchild, D. G.* Tests of fungicides for quince spot. <Div. Veg. Path. Bull. No. 3, 1892, pp. 65–68, plates VII and VIII.

The possibility of successfully preventing leaf blight of quince cuttings has been established beyond doubt by investigations carried on by the writer[1] at Geneva.

These experiments show a remarkable tendency of the quince to loss of foliage, and in this respect are corroborative of Thaxter's results with bearing trees. Five to six applications, begun immediately after full formation of the leaves and continued at intervals of two weeks, were found sufficient to perfectly protect cuttings from the disease. A 60-gallon formula proved effective and the caliper of treated cuttings averaged nearly $\frac{3}{16}$ of an inch greater than that of untreated. The study of this disease offers a promising field for future research.

PEACH LEAF CURL.

(*Taphrina deformans* (Berk.) Tul.)

The only experiments which have come to my notice bearing upon the prevention of this disease are those conducted by Benton[2] in California and Taft[3] in Michigan. The experiments of Benton seem to show with considerable clearness that the fungus can be prevented from gaining entrance into the peach foliage if a fungicide be applied just before the buds unfold, but if treatments are postponed until the leaves are fully expanded the parasite gains a foothold and pushes its way into the growing point, from whence it spreads to the young leaves as they are successively formed.

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[1] *Fairchild, D. G.* Experiments in preventing leaf diseases of nursery stock in western New York. <Jour. of Mycol., Vol. 7, 1893, pp. 247–248, plates XXIV, XXV.

[2] *B* [*enton*] *L. E.* An experiment with the "curl leaf" in the university orchard. <Pacific Rural Press, Vol. 40, No. 5, Aug. 2, 1890. I am indebted to Prof. Wickson for providing me with the clipping and to Mr. Benton himself for the reference to his work.

[3] *Taft, L. R.* The Allegan Gazette, Allegan, Mich., July 1, 1893. Unfortunately I have not been able to secure a copy of Prof. Taft's article.

While I do not feel warranted in concluding from Benton's experiments that Bordeaux mixture will prove a specific for the disease, the indications offered by his work are the most hopeful that I have yet seen. These are further corroborated by the results obtained by Taft, which he informs me were entirely successful. The economic importance of the disease certainly warrants extensive experiments upon it.

PEACH ROT.[1]

(*Monilia fructigena* Pers.)

The experiments which have been carried on for the prevention of this disease are meager and nothing conclusive can be drawn from them. Those of Galloway,[2] made in 1891, were entirely negative, and those of Chester[3] made in 1892, while giving considerable hope of success, are by no means conclusive. The amount of fruit destroyed by rot after six applications with a 37-gallon formula, begun April 29 and continued until July 2, was from 13 to 19 per cent, while the loss on the untreated was 32 per cent. It is to be hoped that further experiments on this destructive disease will be carried out.

APPLE BITTER ROT.[4]

(*Glœosporium fructigenum* Berk.)

Although the experiments of Curtiss[5] on this disease pointed to its control by the use of the potassium sulphide as early as 1889, it was not until the present year that Bordeaux mixture has been tried against it. The experiments of Garman,[6] while not extensive enough to be entirely conclusive, are certainly of sufficient importance to warrant the test of the mixture in practice, with fair hopes of success. The 22-gallon formula alone was used. At least four treatments, beginning before the petals fall and continuing at intervals of two weeks, varying somewhat with the weather, are recommended. The same disease, as it occurs on the grape, has not, so far as I am aware, been experimented upon with a view to its prevention.

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[1] This disease has been called peach blight by Dr. Erwin F. Smith when the fungus attacks the young wood and foliage (*see* Jour. of Mycol., Vol. 7, Sept. 10, 1891, p. 36).

[2] *Galloway, B. T.* An experiment in the treatment of peach rot. <Div. Veg. Path. Bull. No. 3, 1892, pp. 60–61.

[3] *Chester, F. D.* Can peach rot be controlled by spraying? <Del. Exp. Sta. Bull. No. 19, Dec., 1892, pp. 16.

[4] Miss E. A. Southworth has suggested the name of ripe rot for this disease, which appears on both apples and grapes (*see* Jour. of Mycol., Vol. 6, 1891, p. 164).

[5] *Curtiss, Geo. G.* Treatment of bitter rot of the apple. <Sec. Veg. Path. Bull. No. 11, 1890, pp. 38–41.

[6] *Garman, H.* Bordeaux mixture for apple pests. <Ky. Exp. Sta. Bull. No. 44, Jan., 1893, pp. 1–24.

APPLE SCAB.

(*Fusicladium dendriticum* (Wallr.) Fuckl.)

The earliest experiments on this disease made in America, although of interest, need not be discussed here, since in none of them was Bordeaux mixture employed. One point is noteworthy, however, that treatments made after the fruit had attained the size of small peas gave only partially successful results.

In the light of our present knowledge on the date of first infection of fruits, this failure is not to be wondered at, as the young flowers of the apple before the petals fall are often seriously affected by the disease, and any treatments begun after this infection, can not, of course, fully prevent the injury. I have observed in Maryland that the scab spots are able to grow beneath a layer of Bordeaux mixture.

The first reference to the use of Bordeaux mixture as a remedy for apple scab seems to be that of Göthe[1] in 1889. This author did not secure any striking results, and records an injury to the fruit from the use of a mixture improperly prepared. At the above date he advised a reduction from the 26 to the 78-gallon formula, recording better results from a 39-gallon than from a 26-gallon formula.

In 1891 Green[2] carried on an excellent series of experiments in the treatment of the disease, which, from its size and the carefulness with which it was carried out, make it, so far as the writer's search has revealed, the most valuable contribution to the subject yet published. The experiments of Taft and Goff with other fungicides than Bordeaux mixture seem to have yielded results which will not bear a careful comparison with those obtained by the use of this latter mixture. It can quite safely be stated that in the treatment of apple scab this mixture has proved more efficacious than any other. From the extensive nature of Green's experiment and the evidence offered by the subsequent experiments of Goff,[3] Lodeman,[4] Munson,[5] and Garman,[6] as well as from the testimony of many practical horticulturists, it may safely be affirmed that the treatment of apple scab is successful from an economic standpoint. The increased size of the fruit from the prevention of the fungus, which has been shown by Green to be considerable, as well as the production of fair fruit, make the increased market value of the crop many times greater than the expense of treatment.

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[1] *Göthe.* Zur Bekämpfung des Apfelrostes. <Gartenflora, 1889, 38. Jahrg., Heft 9, p. 241. Weed has also recorded injury from the use of the mixture upon apples, probably from its improper preparation (*see* "A season's work among the enemies of the horticulturist". <Jour. Columbus Hort. Soc., Vol. 4, Dec., 1889, pp. 94–106).

[2] *Green, W. J.* The spraying of orchards, (1) spraying to prevent apple scab. <Ohio Exp. Sta. Bull. No. 9, Vol. 4, 2d ser., Dec., 1891, pp. 193–212, pls. VIII–XIII.

[3] *Goff, E. S.* Experiments in the treatment of apple scab in Wisconsin. <Div. Veg. Path. Bull. No. 3, 1892, pp. 31–36.

[4] *Lodeman, E. G.* Spraying apple orchards in a wet season. <N. Y. Cornell Exp. Sta. Bull. No. 48, Dec., 1892, pp. 265–298.

[5] *Munson, W. M.* Apple scab (*Fusicladium dendriticum*). <Me. Exp. Sta. Ann. Rept., 1891, 1892, pp. 110–122. Although the fungicides used by Munson did not include Bordeaux mixture, the remarkable effect of early treatments make the work noteworthy in this connection.

[6] *Garman, H.* Bordeaux mixture for apple pests. <Ky. Exp. Sta. Bull. No. 44, Jan., 1893, p. 25.

As above indicated, the treatments to be successful must be made early, and from the knowledge at hand it seems quite probable that the best results will follow such a course of procedure as is here outlined. The first treatment should be made as the fruit buds are unfolding in the spring and the scales upon opening reveal the clusters of young unopened flowers. The second spraying should be done after the young flower clusters are expanded, but before the individual blossoms have opened; and the third application as the petals are falling, indicating that the fruit has set. It is always advisable to make these three applications, but a fourth spraying may possibly be omitted in dry seasons, although if frequent rains occur it should not be postponed beyond the period when the fruit is one-half inch in diameter. Treatments made later than this period have proved to be of doubtful value. The successful results obtained by Green with a 75-gallon formula of the mixture leave scarcely anything to be desired, and such a formula it would seem can safely be recommended. For the first treatment a stronger mixture may be found, after more extended experiments, to be economical.

Paris green may be added with safety to prevent the codling moth, but it should be applied at the time of the second and third sprayings only, at the rate of 1 pound to 200 gallons of the mixture.

GOOSEBERRY POWDERY MILDEW.

(*Sphærotheca morsuvæ* (Schw.) Berk. & Curt.)

Although this disease has been considered by some writers to be easily controlled by the use of potassium sulphide, and there exists some evidence that such control is possible, so far as I am aware no well-conducted experiments have been reported on its treatment with Bordeaux mixture. From my own observations of treatments made by Beach, at the Geneva Agricultural Experiment Station, the results of which have not yet been published, I am led to hope that it will prove successful, but until extensive tests are made no warrant exists for its recommendation.

CURRANT LEAF SPOT.

(*Septoria ribis* (Lib.) Desm.

Our knowledge of the effectiveness of Bordeaux mixture in the prevention of this disease rests upon experiments made by Pammel[1] in 1890 and 1891. The experiments, although encouraging, do not clearly demonstrate the economic value of the use of the mixture. Three treatments did not prove entirely effective, although seven with ammoniacal solution, begun soon after the leaves were fully grown, showed quite striking results. The fact that the author treated at the same time the disease caused by *Septoria* and another malady produced by *Cercospora angustata* makes it difficult to clearly ascertain the effects of the fungicide on either fungus. It must be concluded that if Bordeaux mixture proves effective for this disease, it will need to be used more frequently than in Pammel's experiments.

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[1] *Pammel, L. H.* Treatment of fungous diseases. <Iowa Exp. Sta. Bull. No. 13, May, 1891, pp. 31–51. Treatment of some fungous diseases; experiments made in 1891. <Iowa Exp. Sta. Bull. No. 17, pp. 20.

STRAWBERRY LEAF BLIGHT.

(*Sphærella fragariæ* (Tul.) Sacc.)

It is probable that the unsuccessful use of Bordeaux mixture for this disease, as recorded in the experiments of Pearson[1] and Earle,[2] was due to the fact that the treatments were begun too late in the season and were not repeated sufficiently often. The careful experiments of Garman,[3] reported the same year, seem to corroborate this conclusion, since they indicate quite plainly the efficacy of the mixture. Treatments with the 22-gallon formula of Bordeaux mixture, begun immediately after the removal of the berries and continued at intervals of two weeks until danger from the parasite was past, proved more effective than eau celeste, liver of sulphur, or London purple, and were in most respects entirely satisfactory. It will be necessary to continue the experiments through several years to establish the economic value of such treatments. Whether the increased vigor of the treated plants the following year will warrant the expense of spraying has not yet been determined.

RASPBERRY ANTHRACNOSE.

(*Glœosporium venetum* Speg.)

The experiments to determine the effect of Bordeaux mixture on this disease are very unsatisfactory, and while there is some reason to believe it may prove effective, sufficiently extensive experiments have not been made to warrant its recommendation.[4]

POTATO BLIGHT OR ROT.

(*Phytophthora infestans* (Montaigne) De Bary.)

This disease may be said to be one of those most amenable to treatment. Experiments in its prevention with Bordeaux mixture were first made, according to M. Girard,[1] by Jouet in 1885. These were followed in 1886 by experiments conducted by Fasquelle, but reported to the Societé Nationale d'Agr. de France by Prillieux in 1886.[2] These experiments were merely preliminary to those carried on by Prillieux[3] himself, which, although on a small scale, were quite conclusive. It must be conceded, however, that to Girard is due the credit of conducting the first extensive series of experiments in the treatment of the disease, and the use of Bordeaux mixture in potato fields really dates from his experiments.

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[1] *Pearson, A. W.* Report of A. W. Pearson, strawberry leaf blight. <Sec. Veg. Path. Bull. No. 11, 1890, p. 49.

[2] *Earle, F. S.* Report of F. S. Earle. <*Ibid.*, pp. 84, 85.

[3] *Garman, H.* Some strawberry pests; the strawberry leaf blight fungus. <Ky. Exp. Sta. Bull. No. 31, Dec., 1890, pp. 3–13.

[4] *Green, W. J.* Treatment of raspberry anthracnose. <Ohio Exp. Sta. Bull. No. 6, Vol. 4, 2d ser., Oct., 1891, pp. 119–121.

In America, as lately pointed out by Galloway,[4] this disease is of comparatively rare occurrence, and many of the experiments, notably those of Weed,[5] were probably against another disease, with which *Macrosporium solani* seems to be invariably connected.

The striking results obtained by Pearson,[6] and later the more extended experiments of Jones,[7] were undoubtedly with *Phytophthora*, and confirm the results of the French experiments, as far as America is concerned. I am in doubt as to the nature of the potato disease upon which Kinney experimented.[8] Jones's experiments show the superiority of this mixture over ammoniacal solution and a copper carbonate and glue mixture. By far the most extensive tests of this mixture, so far as my knowledge goes, have been made in Belgium by Thienpont,[9] and in England by Voelcker[10] and Whitehead.[11] An examination of these reports will, it is believed convince the most skeptical that the matter of profitably treating potato rot has gone beyond the stage of experimentation. The best results are obtained by preventive applications, beginning at least two weeks before the accustomed appearance of the disease, and repeating at intervals of fourteen days. Two or three applications, depending upon the weather conditions, have proved sufficient, but in case of unusually rainy weather four applications may be found necessary. Two curative treatments, begun on the first appearance of the disease, have proved remarkably satisfactory, but according to Thienpont are not as profitable as preventive treatments. A single treatment has been shown quite clearly by Voelcker to yield only inferior results. There is some belief that the mixture acts as a stimulus upon the potato plant, increasing the carbon assimilation, although no experiments have been made to prove this. The yield of tubers from treated plants as compared with untreated varies greatly, but has reached as high as 69 bushels increase per acre of treated plants.

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[1] *Girard, Aimé.* Traitement de la maladie des pommes de terre par les sels de cuivre. <Rev. Horticole, 62e ann., No. 13, July 1, 1890, pp. 301-304; *see also* Compt. Rend., t. 110, 1890, pp. 1089-1092, and Jour. d'Agr. Prat., t. 1, 54e ann., 1890, pp. 803-806.

[2] *Prillieux.* Jour. d'Agr. Prat., t. 2, 50e ann., 1886, p. 886.

[3] *Prillieux.* Expérience de traitement de la maladie des pommes de terre. <Jour. d'Agr. Prat., t. 2, 52e ann., 1888, pp. 264, 265.

[4] *Galloway, B. T.* Proc. Am. Asso. Adv. Agr. Sci., 1893, p. 46.

[5] *Weed, C. M.* An experiment in preventing the injuries of potato rot (*Phytophthora infestans*). <Jour. of Mycol., Vol. 5, pp. 158-160.

Burrill, T. J., and *McCluer, G. W.* Use of fungicides upon the apple, the potato, and the grape. <Ill. Exp. Sta. Bull. No. 15, 1891, pp. 489-496.

[6] *Pearson, A. W.* Report of Col. A. W. Pearson. <Sec. Veg. Path. Bull. No. 11, 1890, pp. 47-49.

[7] *Jones, L. R.* Potato blight and rot. < Vt. Exp. Sta. Bull. No. 24, May, 1891, pp. 19-32; also Fifth Ann. Rept. of same station, 1891, pp. 130. 131.

[8] *Kinney, L. F.* Downy mildew of the potato blight. The Bordeaux mixture as a preventive of the potato blight, experiments with at this station. < R. I. Exp. Sta., Third Ann. Rept., part 2, Jan., 1891, pp. 137-152.

[9] *Thienpont, E.* Le traitement de la maladie de la pomme de terre. Rapport sur des expériences faites en Belgique et en Hollande pendant l'année 1890. Bruxelles, 1891, pp. 49, 80. This is a most convincing treatise on the subject, and settles beyond dispute the profitableness of the use of Bordeaux mixture.

[10] *Voelcker, J. A.* The Woburn experiments on prevention and cure of potato disease. < Jour. Royal Agr. Soc. of England, 3d ser., Dec. 31, 1892, Vol. 3, pp. 771-783.

[11] *Whitehead, Charles.* Report on experiments on prevention and cure of potato disease. < *Ibid.*, pp. 761-771.

POTATO LEAF BLIGHT OR MACROSPORIUM DISEASE.

(*Macrosporium solani* Rav.)

Experiments by Weed,[1] Hunn,[2] Goff,[3] and Burrill and McCluer,[4] point quite conclusively to a control of this disease by treatments with Bordeaux mixture. The recent results of Galloway's experiments[5] admit of no further doubt in the matter. The treatments to be most successful must be at least three in number, begun shortly before the usual appearance of the disease and continued at intervals of two to three weeks, according to the climatic conditions. The increase in yield of treated over untreated plants seems to warrant its use in practice.

POTATO SCAB.

(*Oöspora scabies* Thaxter.)

Bordeaux mixture has been tested as a preventive of this disease by Beach,[6] Kinney,[7] and Bolley,[8] and incidentally by Weed,[9] and although it has shown results indicating its partial effectiveness, its efficacy is so far inferior to that obtained by the use of mercuric bichloride as to make its abandonment almost certain. The diseased seed was soaked in the mixture (22-gallon formula) and the soil treated with it before the planting of the potatoes, but without satisfactory results. The results of Bolley, in part corroborated by those obtained by Beach, make the use of corrosive sublimate promising, although field practice has not as yet shown its economic value. While treatments with Bordeaux mixture gave at least 50 per cent of diseased tubers when diseased seed was used, immersion of the seed tubers for one and a half hours in a solution of mercuric bichloride (2 ounces in 15 gallons of water) saved all but 2 per cent from the disease.

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[1] *Weed, C. M. loc. cit.*

[2] *Hunn, C. E.* Bordeaux mixture used to prevent potato blight. <N. Y. Exp. Sta. Bull. No. 49, n. ser., Jan., 1893, pp. 13-16.

[3] *Goff, E. S.* Bordeaux mixture as a preventive of potato rot. <Report of Div. of Veg. Path. 1890, p. 400; also Rural New Yorker, June 13, 1891, Vol. 50, p. 453.

[4] *Burrill and McCluer, loc. cit.*

[5] *Galloway, B. T.* Proc. Soc. Promotion of Agr. Sci., 1893, pp. 46-58.

[6] [*Beach, S. A.*] Treatment of potato scab. <N. Y. State Exp. Sta. Bull. No. 49, n. ser., Jan., 1893, pp. 3-13.

[7] *Kinney, L. F. loc. cit.*

[8] *Bolley, H. L.* Potato scab and possibilities of prevention. <N. Dak. Exp. Sta. Bull. No. 4, Dec., 1891, pp. 1-14, 21-31. Prevention of potato scab. <*Ibid.*, Bull. No. 9, Mar., 1893, pp. 27-41. These are the best experiments which have been reported upon this disease.

[9] *Weed, C. M.* An experiment in preventing the injuries of potato rot. <Jour. of Mycol., Vol. 5, Sept., 1889, p. 160.

BEAN ANTHRACNOSE.

(*Colletotrichum lindemuthianum* Sacc. and Magn.)

The principal experiments upon the prevention of this disease have been carried on by Beach,[1] and although very promising, need to be repeated upon a larger scale in order to warrant definite conclusions as to their economic value. The experiments have clearly pointed out the advisability of using only healthy seed and the unprofitableness of attempting to disinfect beans already spotted or attacked by the parasite. They have further demonstrated, as far as one year's experiments can, the possibility of protecting the foliage and pods from the fungus by four sprayings with Bordeaux mixture, begun before blossoming and continued at intervals of two weeks. A 90-gallon formula was used, enough Ivory soap being added to make suds. The diseased pods from treated vines were notably less in number than from untreated, and the foliage was strikingly superior, but whether or not the increase in fair pods and vigor of plants will warrant the use of Bordeaux mixture in the field when healthy seed is used is a question as yet unsettled.

DOWNY MILDEW OF THE TOMATO.

(*Phytophthora infestans* (Montaigne) De Bary.)

The experiments upon this disease do not warrant a recommendation of Bordeaux mixture, except tentatively. Calaret[2] has reported its successful use, but without sufficiently definite experiments.

BLACK ROT OF THE TOMATO.

(*Macrosporium solani* Rav.)

Our knowledge of the prevention of this disease by the use of Bordeaux mixture seems to be limited to that furnished by a single experiment conducted in South Carolina by Howell.[1] The results were so decidedly successful, however, as to warrant a more extended trial, but many more experiments will be necessary to establish its profitableness when used on a large scale. The treatments, although not begun until after the disease appeared, saved all but 4 per cent from the rot as compared with 60 per cent destroyed on untreated vines. Three applications were made at intervals of fourteen to fifteen days, beginning when the fruit was three-fourths of an inch in diameter.

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[1] *Beach, S. A.* Some bean diseases. <N. Y. Agr. Exp. Sta. Bull. No. 48, n. ser., Dec., 1892, pp. 308-332.

[2] *Calaret.* La bouillie bordelaise et les tomates. <Jour. d'Agr. Prat., t. 2, 50^e ann., 1886, p. 399.

DOWNY MILDEW OF THE BEET.

(*Peronospora schachtii* Fuckl.)

So far as the writer is aware the simple experiment of M Girard,[2] reported in 1891, is the only one which has been made with a view of preventing this disease. In this experiment Bordeaux mixture, 26-gallon formula, when applied only once after the first appearance of the disease, although not enabling the beets to attain their normal size, effectually checked the spread of the parasite and increased the percentage of sugar above that stored up by the untreated beets. This amount did not equal that found normally in beets growing where no disease is present.

CRANBERRY GALL FUNGUS.

(*Synchytrium vaccinii* Thomas.)

The experiments of Halsted[3] upon this disease do not admit of any great hope that Bordeaux mixture will prove a specific for it.

CRANBERRY SCALD.

Like the cranberry gall fungus, the parasite causing the disease has not shown itself amenable to treatment.[4]

MIGNONETTE LEAF BLIGHT.

(*Cercospora resedæ* Fuckl.)

A simple experiment by the writer[5] with potted plants carried on in the greenhouse of the Department of Agriculture, showed quite plainly the efficacy of this mixture as a preventive. The trial was not extensive nor was it repeated, and, furthermore, it was carried on under somewhat abnormal conditions. Bordeaux mixture proved superior to ammoniacal solution, and will probably be quite efficient in holding the disease in check if applied before it appears. The 22-gallon formula was used in the experiment, three applications being made, and no objectionable spotting of the flowers was evident. This is, so far as I am aware, the only experiment which has been made for the prevention of the disease.

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[1] *Howell, A. M.* Experiments in the treatment of tomato rot. <Sec. of Veg. Path. Bull. No. 11, 1890, pp. 61–65.

[2] *Girard, Aimé.* Destruction du Peronospora schachtii a l'aide des composés cuivriques. <Jour. d'Agr. Prat., t. 2, 53e ann., 1891, pp. 15, 16.

[3] *Halsted, B. D.* Experiments for the year on cranberry diseases. <Rept. N. J. State Board of Agr., Vol. 18, 1891, pp. 266–272.

[4] *Halsted, B. D.* The cranberry scald. <Garden and Forest, Vol. 4, Nov. 4, 1891, p. 524.

[5] *Fairchild, D. G.* A mignonette disease (*Cercospora resedæ* Fuckl.). <Ann. Rept. of Sec. Veg. Path. in Ann. Rept. Dept. Agr. for 1889, pp. 429–432.

LEAF SPOT OF CHRYSANTHEMUMS.

(*Septoria* sp.)

Beach[1] has carried on a single experiment with this disease, which, although not entirely conclusive, points strongly towards its control by the 66-gallon formula of Bordeaux mixture to which enough soap was added to form suds. The dead leaves must be removed and the green parts kept covered with the mixture. Five or six treatments were found necessary.

LOOSE SMUT OF WHEAT.

(*Ustilago tritici* (Pers.) Jensen.)

Kellerman's[2] experiments to test the efficacy of Bordeaux mixture as a seed treatment for this disease were entirely negative and leave little hope that it will prove of value in treating loose smut of wheat.

STINKING SMUTS OF WHEAT.

(*Tilletia fœtens* (B. and C.) Trel., and *T. tritica* (Bjerk.) Wint.)

The experiments of Kellerman and Swingle[3] have shown Bordeaux mixture to be partially successful in the treatment of seed wheat for this disease, but the results obtained by the use of the Jensen hot water method so far excel it as to make further mention of the matter here superfluous.

CORN SMUT.

(*Ustilago maydis* Lév.)

The experiments[4] in the prevention of this disease have been entirely negative, as they did not take into account the possibility of infection by the parasite of the young meristematic tissue offered by the young growing point of the corn plant during its whole period of growth. It has been shown by Brefeld that the period of susceptibility of the corn plant is not confined to the early stage, as it is in case of the smuts of cereals.

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[1] *Beach, S. A.* Leaf spot of chrysanthemums. <Eleventh Ann. Rept. N. Y. State Exp. Sta., for 1892, pp. 557–560.

[2] *Kellerman, W. A.* Test of fungicides to prevent loose smut of wheat. <Kans. Exp. Sta. Bull. No. 22, Aug., 1891, pp. 81–90.

[3] *Kellerman, W. A., and Swingle, W. T.* Preliminary experiments with fungicides for stinking smut of wheat. <Kans. Exp. Sta. Bull. No. 12, Aug., 1890, pp. 27–51. Second report on fungicides for stinking smut of wheat. <Kans. Exp. Sta. Bull. No. 21, Aug., 1891, pp. 47–72.

[4] *Kellerman, W. A.* Corn smut. <Kans. Exp. Sta. Bull. No. 23, Aug., 1891, pp. 101–104.

RUSTS OF CEREALS.

(*Puccinia rubigo-vera* (DC.) Wint., *P. coronata* Corda, and *P. graminis* Pers.)

Several well-conducted and extensive experiments have lately been made to ascertain if the rusts of cereals can be prevented by the use of Bordeaux mixture, and while no remarkable success has attended these attempts, the mixture has proved itself superior to many other fungicides employed. In fact it has shown itself to be the only one which to any marked degree prevents the attacks of the parasites. The difficulties lying in the way of the prevention of these diseases are in large part owing to the peculiar nature of the host plants themselves. The waxy cuticle of the leaves resists the wetting power of ordinary Bordeaux mixture, and only after soap is added to the fungicide is it enabled to thoroughly coat the parts exposed to the attacks of the fungi. Furthermore, the resistant power of the spores to the action of copper probably plays an important part in nullifying the results. Wüthrich[1] from his laboratory investigations has even gone so far as to say that he doubts if the copper compounds can ever be employed as fungicides strong enough to obtain the same results as have been secured in the treatment of the *Peronosporaceæ*. He bases his belief on the remarkably resistant power of the uredo and æcidiaspores to a solution of copper sulphate. How far this author was correct in his belief has been well illustrated by the results of recent experiments. The above statement is not intended, however, to give the impression that all future experiments with copper preparations are likely to prove futile: in fact the slight advantages shown quite clearly in the numerous experiments of Galloway,[2] notably those carried on in Kansas, are in a measure encouraging. In these experiments a very perceptible decrease in the amount of rust followed treatments with Bordeaux mixture (22-gallon formula), repeated every ten days from the time the young plants appeared above ground until harvest. This is especially noteworthy as no soap was employed in the mixture and the plats used were large enough to give a fair comparison, and requires an explanation before the struggle against these parasites is abandoned along this line. Kellerman's[1] experiments with wheat rust showed Bordeaux mixture to be slightly beneficial, while the experiments of Hitchcock and Carleton[2] on oats and barley were entirely negative, and in this respect similar to those of Galloway on the same cereals.[3] The somewhat ambiguous statement lately made by Cobb[4] that Bordeaux mixture has proved effective against rust of wheat, has led to its being misquoted in one of the station bulletins.

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[1] *Wüthrich, E., op. cit.* <Zeit. f. Pflanzenkrank., Bd. 2, Heft 2, pp. 93, 94. The author here remarks: "Mit Rücksicht auf das ungleiche Verhalten der letzteren Fungiciden gegenüber erscheint es als wahrscheinlich, dass eine *direkte Bekämpfung der Rostkrankheiten nie den Erfolg haben wird, wie bei den Peronosporeen.*"

[2] *Galloway, B. T.* Experiments in the treatment of rusts affecting wheat and other cereals. <Jour. of Mycol., Vol. 7, 1893, p. 214, table 5, p. 224.

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[1] *Kellerman, W. A.* Spraying to prevent wheat rust. <Kans. Exp. Sta. Bull. No. 22, Aug., 1891, pp. 90–93.

[2] *Hitchcock, A. S., and Carleton, M. A.* Preliminary report on rusts of grain. <Kans. Exp. Sta. Bull. No. 38, Mar., 1893, pp. 14.

[3] *Galloway, B. T. loc. cit.*, pp. 212, 213, 225.

[4] *Cobb, N. A.* Contributions to an economic knowledge of Australian rusts (Uredineæ). <Agr. Gaz. N. S. Wales, Vol. 3, p. 187.

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